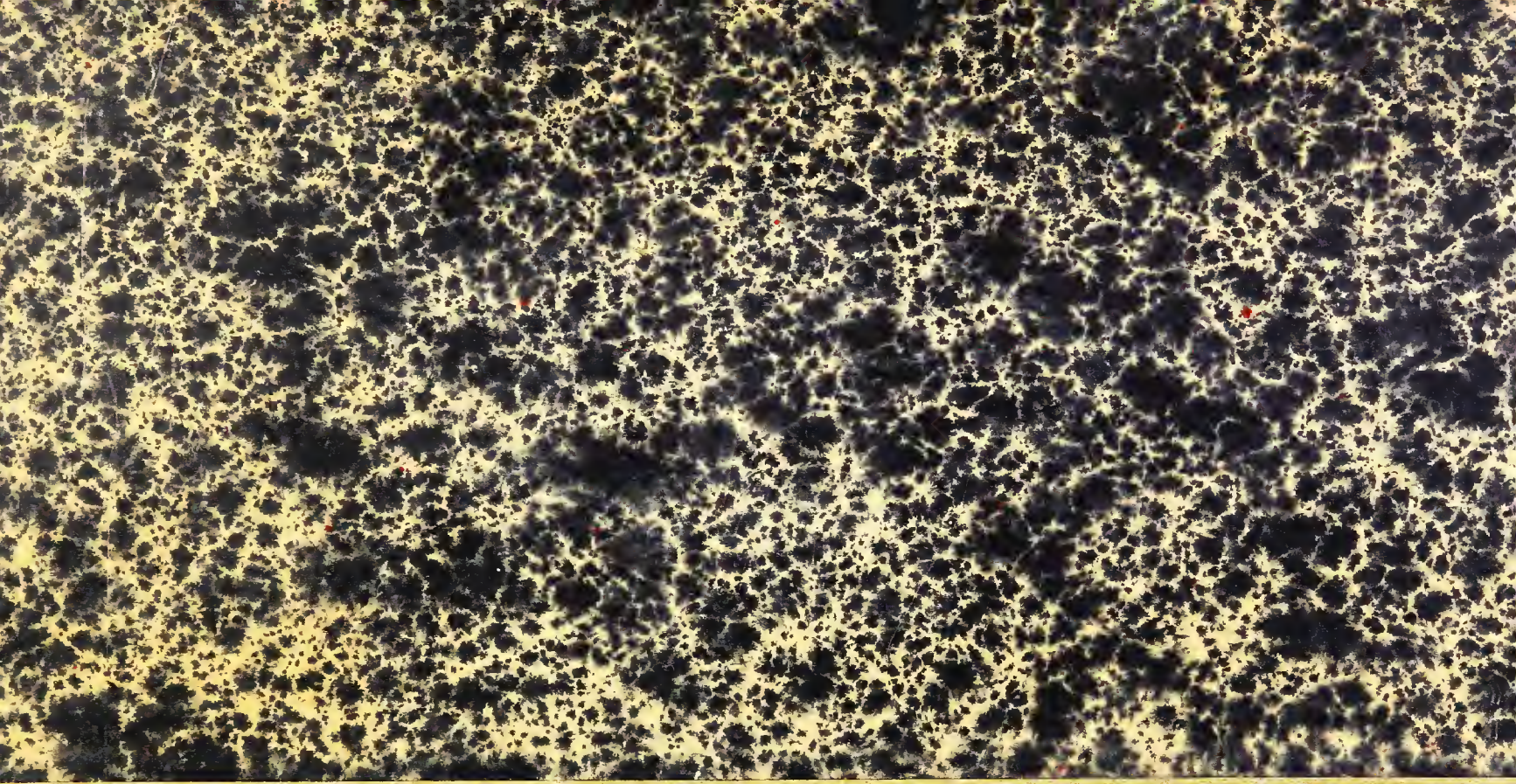

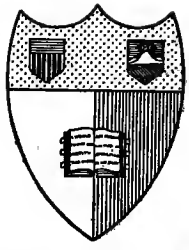

MEMOIRS OF THE GEOLOGICAL SURVEY

ENGLAND AND WALES

ON THE

THICKNESSES OF STRATA

IN THE

COUNTIES OF ENGLAND AND WALES

EXCLUSIVE OF ROCKS OLDER THAN THE PERMIAN.

BY

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156. ATHERSTONE and CHARNWOOD	11 3	1 6	2 0
166. LEICESTER	8 3	1 6	3 0
187. HUNTINGDON	—	6 0	—
203. BEDFORD	—	9 9	—
228. HAVERFORDWEST ...	—	—	3 6
229. CARMARTHEN	1 6	1 6	2 0
230. AMMANFORD	1 6	1 6	2 6
231. MERTHYR TYDFIL ...	1 6	1 6	1 6
232. ABERGAVENNY	1 6	1 6	2 0
246. WEST GOWER	1 6	1 6	0 6
247. SWANSEA	1 6	1 6	2 6
248. PONTYPRIDD	1 6	1 6	1 6
249. NEWPORT (Mon.) ...	1 6	1 6	1 6
254. HENLEY-ON-THAMES ...	—	1 6	2 0
261-2. BRIDGEND	1 6	1 6	1 6
263. CARDIFF	1 6	1 6	2 0
267. HUNGERFORD and NEWBURY	—	1 6	2 6
268 READING	6 9	1 6	1 6
269. WINDSOR	—	—	2 6
282. DEVIZES	—	1 6	1 0
283. ANDOVER	—	1 6	1 6
284. BASINGSTOKE	—	1 6	2 0
295. TAUNTON and BRIDGWATER	—	1 6	2 0
296. SALISBURY	—	1 6	1 3
299. WINCHESTER	—	1 6	1 6
300. ALRESFORD	—	1 6	2 0
311. WELLINGTON and CHARD	—	1 6	1 3
314. RINGWOOD	—	1 6	1 0
315. SOUTHAMPTON	—	1 6	1 6
316. HAVANT	—	1 6	1 9
317. CHICHESTER	—	1 6	1 0
325. EXETER	—	1 6	2 0
326 and 340. SIDMOUTH and LYME REGIS ...	—	1 6	1 6
328. DORCHESTER	—	1 6	1 0
329. BOURNEMOUTH	6 3	1 6	0 4
330. NEW FOREST (pts.), I. of WIGHT (pts) ...	7 6	1 6	—
331. PORTSMOUTH and I. OF WIGHT (pt.)	6 3	1 6	—
332. BOGNOR	2 0	1 6	0 8
333. WORTHING and ROTTINGDEAN	—	1 6	—
334. NEWHAVEN and EASTBOURNE	—	1 6	0 6
335. TREVOSE HEAD	—	1 6	2 3
336. CAMELFORD	—	1 6	
337. TAVISTOCK and LAUNCESTON	—	1 6	3 0
338. DARTMOOR	—	1 6	2 3
339. NEWTON ABBOT	—	1 6	3 0
341. WEST FLEET	—	1 6	
342. PORTLAND and WEYMOUTH	—	1 6	10 6
345. SWANAGE	—	1 6	
346. NEWQUAY	—	1 6	3 0
347. RODMIN and ST. AUSTELL	—	1 6	4 0
348. PLYMOUTH and LISKEARD	—	1 6	1 6
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PREFACE.

This Memoir is designed to give such records of the thicknesses of strata in England and Wales, as are founded on reliable measurements of open sections or on results obtained from borings. The investigation, however, is not carried below the Permian group. The thicknesses of the Carboniferous rocks, especially as regards the Coal Measures, are already recorded so fully in other publications that it seemed inadvisable to add to the bulk of this volume by repeating them. The older Palæozoic rocks also are left out of account. Their dimensions are always difficult and often impossible to ascertain, nor would any practical purpose be served by attempting to do so.

The records are grouped under counties and the counties are arranged alphabetically. The arrangement is not free from objection, for it involves the ignoring of the geographical position of the counties, and does not facilitate the tracing of the changes in dimensions undergone by each formation in its range through the kingdom. On the other hand, to have completed the account of each formation separately throughout its range would have involved much repetition, and would have rendered it difficult for the reader to ascertain the sequence of strata likely to be met with at any one locality. Such confusion as may be caused by the alphabetical arrangement has been minimised by inserting the names of adjacent counties on each county map.

Difficulties, not wholly unforeseen, arose after the work had been commenced. Discrepancies in measurements in closely adjoining sections or boreholes were in some cases so great as to raise doubts as to the correctness of the classification. In such formations as the Selbornian for example, the plane of separation between the sandy member (the Upper Greensand), and the clay-member (the Gault), is ill-defined and is not likely to have been placed at the same horizon in independent observations. While, therefore, there are great variations in the recorded thickness of either of these members, the aggregate thickness of the two together is a more significant measurement.

That rapid variations would have to be recorded in the subdivisions of the Wealden was anticipated. Not only do the sand- and clay-beds graduate one into the other, but the subdivisions shown upon the Geological Survey Map all, more or less, have a lenticular form. Of the Oolitic subdivisions also few lend themselves to a precise lithological definition.

The general question of correlation has not been touched. It would be out of place for example to enquire what strata in the Southern Counties correspond in age to the Tealby and Speeton Beds of the North. The practical purpose is served by recording the dimensions of each in their respective districts.

The occurrence of unconformities raises a more serious question from the point of view of the scientific geologist. A large proportion of the records are founded on boreholes. Fossil evidence is generally scanty under such circumstances, and there has seldom been sufficient opportunity for studying the relations

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of the formations to one another. Without doubt, gaps ranging in magnitude from a pronounced unconformity to a slightly incomplete sequence, frequently occur. It must not be assumed, therefore, that the records give the full development originally attained by the formations in all localities. For example, in the Richmond boring (p. 135), 87½ ft. does not represent the original development of the Oolites; a part was removed by denudation before the Lower Greensand was laid down. On the other hand, this and other records furnish evidence of the position of a shore-line along which the Oolitic sediments were deposited, and past which some of the Oolitic formations never extended.

Each section of the Memoir is accompanied by a map of the county or counties described. All names mentioned in the text are inserted when possible, but not necessarily all towns. The maps are intended merely to enable the reader to locate the records. They show also the divisions of the New Series one-inch maps.

The preparation of the Memoir was originally undertaken by Mr. C. Fox-Strangways. When he died, before a commencement had been possible, it became necessary to distribute the work which he had proposed to carry out. The considerable task of collecting records from the publications of the Geological Survey was in the main performed by Mr. T. V. Holmes, formerly a member of the staff. The further work necessary in bringing the records up to date from other sources, published or unpublished, in selecting and tabulating the data and in writing the explanatory text, was carried out by members of the staff.

The Counties of Bedford, Cambridge, Cumberland, Durham, Gloucester, Huntingdon, Lincoln, Norfolk, Northampton, Northumberland, Somerset, Suffolk, Warwick, Westmorland, Worcester and York, with North and South Wales, were dealt with by Mr. W. B. R. King. Five Counties, namely, those of Derby, Leicester, Nottingham, Rutland and Shropshire, were written by Mr. D. A. Wray; Buckingham, Cornwall, Devon and Kent by Mr. H. Dewey; Cheshire and Lancashire by Mr. W. C. Simmons before his resignation, and Wiltshire by Mr. C. H. Cunnington. For the remainder I am jointly responsible with Mr. Holmes.

A. STRAHAN,
Director.

Geological Survey Office,
Jermyn Street, London, S.W.,
2nd December, 1915.

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LIST OF ILLUSTRATIONS.

The Illustrations enumerated on p. v. are all County Maps showing the situations of places referred to in the text, with the exception of :—

BEDFORDSHIRE AND NORTHAMPTONSHIRE.

Table of Strata exposed or proved in borings.

		Thickness in feet.
Superficial	Alluvium and River Gravel	up to 35
	Glacial drift	up to 376
Eocene	Reading Beds	10
Cretaceous	Upper Chalk	100
	Middle Chalk	220
	Lower Chalk	200
	Upper Greensand	up to 20
	Gault	150–300
	Lower Greensand	170–280
Oolitic	Kimmeridge Clay	10
	Corallian (Ampthill Clay)	40–60
	Oxford Clay	300–500
	Kellaways Beds	10–50
	Cornbrash	2–15
	Great Oolite Clay	3–20
	Great Oolite Limestone	7–31
	Upper Estuarine Series	15–30
	Lincolnshire Limestone	0–80
	Northampton Beds	3–68
Liassic	Upper Lias	60–210
	Middle Lias	100
	Lower Lias	500
Found only in borings in Northamptonshire :—		
Triassic	Rhaetic	20–36
	Keuper	27–87
Palæozoic and older rocks		—

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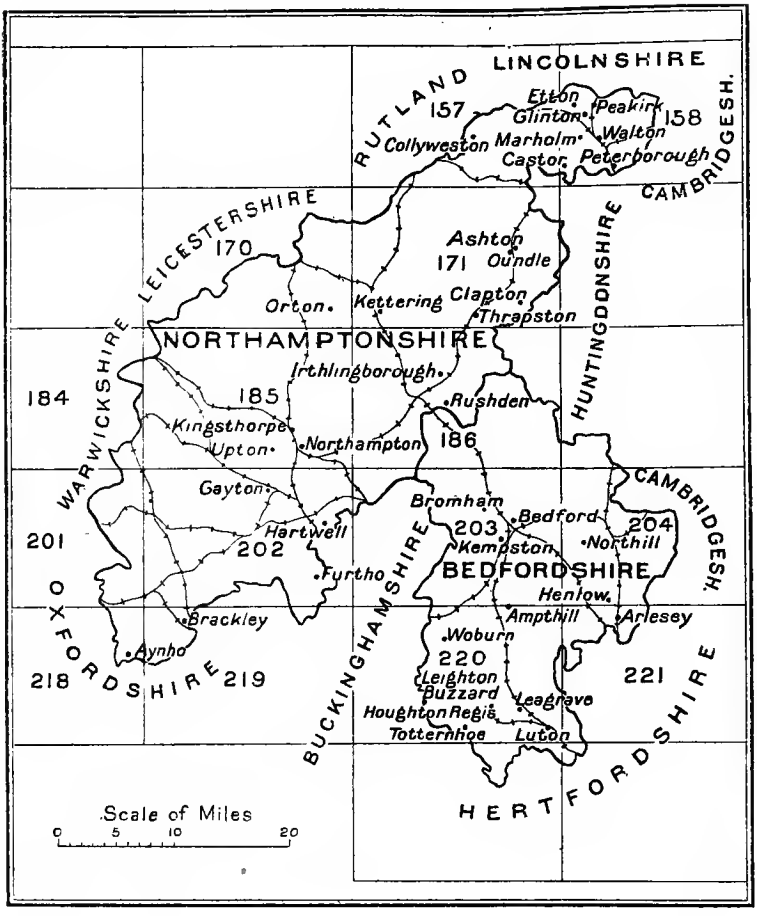
FIG. 1. BEDFORDSHIRE AND NORTHAMPTONSHIRE.



SUPERFICIAL.

Alluvium and River Gravel.

The part of Northamptonshire which lies north of Peterborough is covered by fen-deposits of gravel, silt and peat, to a thickness of about 15 ft.

In the valleys of the Nene and Ouse the gravels reach a thickness of 30 or 35 ft. (10).

Glacial.

The glacial deposits generally consist of boulder-clay with underlying gravels. The gravels, when present, range from 20 to 40 ft. in thickness (10).

The boulder-clay varies from a few feet up to more than 100 ft. In Bedfordshire exceptional thicknesses have been found at Henlow, 376 ft., Northill, 104 ft., and Woburn, 106 ft.; in Northamptonshire at Rushden, 16 ft., and Clapton, 114 ft.

Buried channels have been recorded near Northampton, by Mr. Beeby Thompson; and "at Furtho an old valley of the Ouse has in its midst boulder-clay to a thickness of 100 ft. or more." (7). The drift at Henlow extends to a depth of over 200 ft. below sea-level and is thought to occupy a channel which has been traced past Hitchin.

Eocene.

The Reading beds form a few outliers in the south of Bedfordshire. They have a thickness of about 10 ft.

Cretaceous.

Chalk.

Only the lowest beds of the Upper Chalk occur in Bedfordshire. The greatest thickness present is probably not more than 100 ft.

The Middle Chalk has a thickness of about 220 ft., of which 160 ft. may be assigned to the *Terebratulina* Zone and 60 ft. to that of *Rhynchonella cuvieri* (6).

The Lower Chalk is 200 ft. thick, 80 ft. belonging to the zone of *Ammonites varians* and 120 ft. to the zone of *Holaster subglobosus*. The Totternhoe stone has a thickness of 20 to 22 ft. (6).

Upper Greensand and Gault.

The Upper Greensand has a development of about 20 ft. near Totternhoe but is absent over most of the county (10).

The Upper Gault is estimated as being between 25 to 30 ft. in thickness (9, 5), and the Lower Gault as being from 150 to 180 ft. (5). Another estimate gives the Lower Gault as varying from 150 to 280 ft. (9).

The total thickness of the Gault may be regarded as ranging between 300 ft. in the south to 150 ft. in the east (10).

Lower Greensand.

The Lower Greensand near Leighton Buzzard and Woburn may be from 170 to 280 ft. (10), but it thins to the N.E., being only a few feet thick in parts of Cambridgeshire.

Oolitic.

Kimmeridge Clay.

This formation is found only near Ampthill, where 10 ft. of the lowest beds are believed to be present.

Ampthill Clay.

The Corallian beds are represented in Bedfordshire by the Ampthill Clay. One estimate gives the thickness of that bed as 200 ft. (1), but other records give from 40 to 60 ft. (10). The Ampthill section shows that there it amounts to 61 ft. (4).

Oxford Clay with Kellaways Beds.

The Oxford Clay, in the absence of proof derived from borings, has been estimated to have a thickness of 400 to 500 ft. (10), or 300 to 400 ft. (9). About 10 to 50 ft. of strata are assigned to the Kellaways beds (9, 10).

Cornbrash.

This rubbly limestone varies from 2 to 15 ft. in thickness. Near Bedford it is a single layer of rock (3). Through Northamptonshire it is about 5 ft. thick, but near Peterborough it expands to about 15 ft. (10).

Great Oolite Clay.

The Great Oolite Clay varies from a few feet in Bedfordshire to 10 to 20 ft. in Northamptonshire (10). At Thrapston it is 12 ft. thick (3).

Great Oolite Limestone.

This rock averages 15 to 30 ft. in Bedfordshire (11), while in Northamptonshire it is generally 25 ft. thick (10). It seems to be thinning northwards, as only 7 to 16 ft. are recorded in borings in the Peterborough district.

Upper Estuarine Series.

The Upper Estuarine Series of Bedfordshire varies from 15 ft. to a little over 30 ft. Near Northampton the thickness is 15 ft., and near Bedford 27 ft. (3).

Lincolnshire Limestone.

This is an oolitic limestone of variable development. It is absent in Bedfordshire but reaches 80 ft. in the northern part of Northamptonshire. It is absent at Peterborough and Oundle (10).

In the north-western part of Northamptonshire the basal part, for a thickness of 2 to 10 ft., is sandy, and constitutes the Collyweston Slate (3).

Northampton Beds.

These sands have a maximum thickness of 70 or 80 ft. The general thickness is about 14 ft. in Northamptonshire.

Some 12 ft. of sands in Bedfordshire have been referred to this horizon, but they are known only in borings (9).

Liassic.

The Upper Lias of Bedfordshire is between 60 and 70 ft. thick (10). Near Northampton, 180 to 190 ft., in the south-west of the county 140 ft., and in the north-east, towards Peterborough, only about 85 ft., represent the thicknesses of clays assigned to this subdivision.

The Middle Lias, so far as regards Bedfordshire, may have a thickness of 97 ft. assigned to it.

In Northamptonshire it has a thickness of about 100 ft. At Orton, west of Kettering, a boring showed 6 ft. of Marlstone and 112 ft. of Middle Lias Clay (2).

The Marlstone group ranges up to 21 ft. at Northampton and 40 ft. in the western parts of the county (10).

The Lower Lias is about 500 ft. thick in Northamptonshire. The Upper Clay group is about 350 ft. and the Lower Limestones and Clay group about 150 ft. (2, 10).

At Orton the Lower Lias was 531 ft.

Triassic.

The Rhaetic beds have been found in four borings in Northamptonshire. The united thicknesses of the White Lias and the black shales amounted to 36 ft. at Gayton. At Kingsthorpe 20 ft. of conglomerate containing limestone-pebbles are recorded as occurring between the Lias and Trias.

The Keuper beds consist of red marls, sandstones and conglomerates. At Kingsthorpe they were sunk into for 87 ft., and at Gayton and Orton were proved to be 82 ft. and 27½ ft. respectively.

The Bunter was absent in all the borings.

PRINCIPAL BORINGS IN BEDFORDSHIRE AND NORTHAMPTONSHIRE. (*Thicknesses in feet.*)

	BEDFORDSHIRE.											NORTHAMPTONSHIRE.																	
	Luton.	Leagrave.	Houghton Regis.	Leighton Buzzard.	Woburn.	Arlesey.	Kempston.	Bedford.	Bromham.	Henlow.	Northill.	Brackley.	Hartwell.	Gayton.	Upton.	Northampton.	Kingsthorpe.	Rushden.	Irthlingborough.	Orton.	Clapton.	Ashton.	Peterborough.	Castor.	Walton.	Marholm.	Etton.	Glinton.	Peakirk.
Alluvium	–	–	–	10	–	–	–	8	3	–	–	–	7	8	–	–	–	–	1	–	1½	–	30	13	–	2	13	9	9
Glacial	–	–	–	–	106	7	–	–	–	376	104	–	32	–	10	–	–	16	–	–	114½	76	–	–	–	–	–	–	–
Reading Beds ...	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Upper Chalk ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Middle Chalk ...	150	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lower Chalk ...	170 to	39 to 269	70 276	– 32 to 109	– – to 163	– 324 to 133½	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gault	–	–	181 to 18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lower Greensand ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kimmeridge Clay ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ampthill Clay ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oxford Clay ...	–	–	–	–	–	–	104	–	–	–	100	–	–	–	–	–	–	45	–	–	126½	20	27½	–	–	20	20	33	48
Kellaways Beds ...	–	–	–	–	–	–	19	25	17	–		–	–	–	–	–	–	–	–	–									
Cornbrash	–	–	–	–	–	–	3	2½	1½	–	2½	–	–	–	–	–	–	5	2	–	9	6	6½	–	1	6	7½	6	8½
Gt. Oolite Clay and Forest Marble.	–	–	–	–	–	–	7	3	8	–	to 15	–	–	–	–	–	–	10	11½	–	3½	9½	13½	6½	14	14	14¼	13½	10
Gt. Oolite Limestone	–	–	–	–	–	–	26 to 14	31½ to 7	24 17	–	–	52	27 13	–	–	–	34	13½ 12½	25½ 17	–	22½ 67*	17½ 44*	7½ 31	7 7	14 24	15½ 20	12 38½ to 13½	12 31	16 28½ to 33
Up. Estuarine Series	–	–	–	–	–	–				–	–			–	–	–				–									
Lincolnshire Limestone.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	77		72½	

Northampton Beds .	–	–	–	–	–	–	–	–	–	? to 30	–	–	8 to 26	3 to 136	–	68 to 100	18 to 25	49 to 100	3 to 6½	30 to 10	–	– to 113	– to 29	17½ to 93	15½ to 230	28 to 220	– to 9	–	– to 24	–	–
Upper Lias ...	–	–	–	–	–	–	–	–	–		–	–	109	112	½	183	153	183	–	–	48										
Middle Lias ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100	25	100	100	–	–	87	–	–	–	–	–	–	–	–	–	–
Lower Lias ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	472½	–	467	494	–	–	531	–	–	–	–	–	–	–	–	–	–
Rhaetic	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36	–	27	20 to 87	–	–	22	–	–	–	–	–	–	–	–	–	–
Keuper	–	–	–	–	–	–	–	–	–	–	–	–	–	–	82	–	40½ to 45½		–	–	27½	–	–	–	–	–	–	–	–	–	–
Carb. Limestone ...	–	–	–	–	–	–	–	–	–	–	–	–	–	–	190 to 105	–	–	–	–	–	– to 74	–	–	–	–	–	–	–	–	–	–
? Old Red Sandstone	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–
Volcanic (Archaean)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–

* This includes all strata between the Great Oolite Limestone and the Upper Lias.

BERKSHIRE AND OXFORDSHIRE.

Table of Strata exposed or proved in borings.

		Thickness in feet.
Superficial...	Alluvium, Gravels, &c....	——
Eocene ...	Upper Bagshot Sand (top absent) ...	to 200
	Bracklesham Beds	40–60
	Lower Bagshot Sand	100–120
	London Clay	50–350
	Reading Beds	70–90
Cretaceous	Upper Chalk	300–340
	Middle Chalk	150–200
	Lower Chalk	200–240
	Upper Greensand, 30 to 75 ft. } Selbornian.	240–300
	Gault, 190 to 264 ft. ... }	
	Lower Greensand	0–100
	Wealden	0–50
Oolitic ...	Purbeck Beds	up to 4
	Portland Beds	0–100
	Kimmeridge Clay	100–200
	Corallian	80–100
	Oxford Clay, about	450
	Cornbrash	10–21
	Forest Marble	18–38
	Great Oolite and Upper Estuarine Series	100–180
	Inferior Oolite	7–36
	Northampton Sand	0–17
Liassic ...	Upper	14–82
	Middle	65–100
	Lower	447
	Proved in borings only :—	
Triassic ...	Rhaetic ... ... }	0–467
	Keuper Marl ... ... }	
Palæozoic ...	... ...	——

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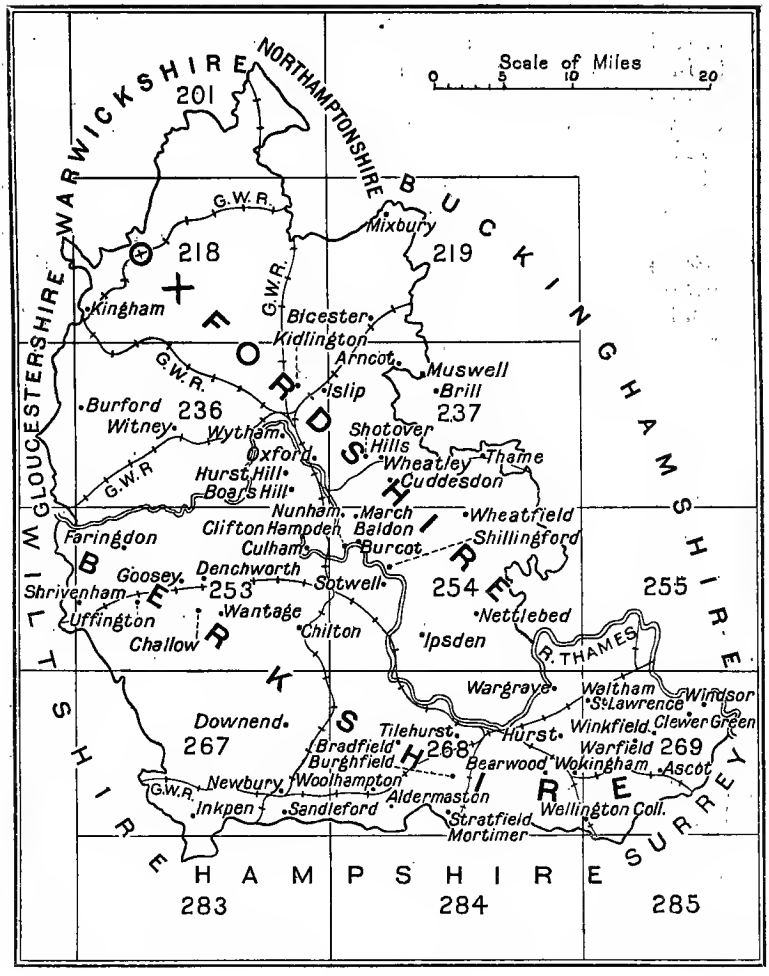
SUPERFICIAL.

The superficial deposits vary greatly. Thus, near Old Windsor Lock, valley-drift (gravel and sand) was 16 ft. thick; at Clewer Green, valley-drift (clay above gravel) was 8 ft.; and at a brewery in Thames Street, Windsor, 25 or 30 ft. of gravel lay on Chalk (1).

FIG. 2. BERKSHIRE AND OXFORDSHIRE.



EOCENE.

Bagshot Beds.

In Berkshire the Bagshot Beds include an upper division of buff or whitish sand which occurs in outliers only, and of which the full thickness is nowhere present; a middle division, known also as the Bracklesham Beds, which consists of yellow and green glauconitic sand and brownish laminated clays, and attains a thickness of 40 to 60 ft.; a lower division of brown or white sand with thin beds of clay, which reaches a thickness of 100 to 120 ft. in the south-eastern part of the county, but is not so thick elsewhere.

The greatest thickness of Bagshot Beds traversed in one boring was found at Wellington College, Sandhurst, where the Upper Bagshot (top absent) and the Bracklesham Beds together accounted for 82 ft. and the Lower Bagshot for 110 ft. (7).

London Clay.

In Berkshire the London Clay reaches its greatest development of 350 ft. towards the east and dwindles thence to little more than 50 ft. in the western part of the county. The following thicknesses in feet are extracted from well-records and are arranged in geographical order from east to west:—Old Windsor, more than 197; Ascot, 349½; Wellington College, 346; Wokingham, more than 273; Woolhampton, 176; Sandleford, 118½; Newbury, 61; Inkpen, 52. The thickness at Sandleford as compared with that at Newbury indicates a southward expansion, which is rendered probable by a consideration of the development in Hampshire (p. 66). The identification of the top and bottom of the London Clay, however, is difficult in boreholes (7), and the thickness at Newbury may be slightly greater than that given.

In Oxfordshire the London Clay occurs as small outliers only.

Reading Beds.

In Berkshire the Reading Beds consist of variously coloured clays in the upper part, with a thickness of 30 to 50 ft.; and of brown or green sands in the lower part, with a thickness of 20 to 40 ft. The total thickness varies from less than 70 to 90 ft.

Borings at the following places have proved the full thickness of Reading Beds. The localities are arranged approximately in geographical order from east to west, and the thicknesses are given in feet:—Windsor, 70 to 87; Ascot, 73; Winkfield, 78; Warfield, 78; Waltham St. Lawrence, 61; Wellington, 66; Wokingham, 70; Bearwood, 86; Hurst, 68; Tilehurst, 51 to 47; Burghfield, 76 to 70; Stratford Mortimer, 69; Bradfield, 68 to 74; Aldermaston, 70 to 73; Newbury, 80; Sandleford, 92; Inkpen, 75. It appears that the westward attenuation of the London Clay is not shared by the Reading Beds, nor is there much variation in a north and south direction between Waltham and Wellington, or between Tilehurst and Stratford Mortimer.

In Oxfordshire the Reading Beds occur as outliers only. At Nettlebed they have been estimated to be about 40 feet thick (1).

Cretaceous.

Chalk.

In Berkshire the Winkfield boring quoted on p. 15 shows 337 ft. of Upper Chalk (including the supposed Chalk Rock), 169 ft. of Middle Chalk (including the supposed Melbourn Rock) and 219 feet of Lower Chalk. Though the exact division into Upper, Middle and Lower is attended with doubt, the total of 725 ft. for the whole of the Chalk seems to be a reliable measurement. At Wargrave the thickness of the Upper Chalk was proved to be 319½ ft. (7). The Chalk Rock consists of hard chalk crowded with nodules, mostly green-coated, and is about 9 ft. thick. The Melbourn Rock at the base of the Middle Chalk is hard and nodular, and about 14 ft. thick. A third rock, known as the Totternhoe Stone occurs in the Lower Chalk, about 70 or 80 ft. below the Melbourn Rock; it is about 2 ft. thick in parts of Berkshire, but has not been identified west of Chilton.

The Winkfield boring gives the only direct measurement of the whole Chalk. In other parts of the county the Middle Chalk is estimated at about 150 ft., and the Lower Chalk at about 220 ft., increasing to 240 ft. in western Berkshire.

In Oxfordshire the Upper Chalk has been estimated at 300 ft. (Nettlebed), and the Middle Chalk as at least 200 ft. (Ipsden), while the Lower Chalk is about 200 ft. thick.

Upper Greensand and Gault (Selbornian).

The Upper Greensand consists in the upper part of 10 to 30 ft. of sand with grains of glauconite, and in the lower part of 50 or 60 ft. of calcareo-siliceous strata, marly in places and containing layers of malmstone and chert. The Gault is a grey or dark bluish clay, graduating upwards into the Upper Greensand and varying from 190 to 264 ft. in thickness.

In Berkshire the thicknesses assigned to the Upper Greensand and Gault respectively were 31 and 264 ft., making a total for the Selbornian of 295 ft. At Wantage the thicknesses were 65 and 229 ft., making a total of 294 ft. At Sotwell a thickness of 75 ft. was attributed to the Upper Greensand.

In Oxfordshire the respective thicknesses of Upper Greensand and Gault have been estimated at 54 and 230 ft., making a total for the Selbornian of 284 ft. (2). At Shillingford 144 ft. of Gault were bored through and the total thickness of the formation is estimated at 190 ft. (8). At Wheatfield 197 ft. (top absent) were proved.

Lower Greensand.

This formation occurs in patches only in Berkshire and Oxfordshire, between the Gault and Upper Oolitic strata. It is absent along the greater part of the outcrop and, as proved in borings, in part of the tract covered by Upper Cretaceous rocks.

In Berkshire it is developed south of Shrivenham, at Faringdon and thence eastwards to near Uffington. It consists of brown and white sand with some ironstone in the upper part, and of ferruginous pebbly gravel containing many fossil sponges in the lower part, with a total estimated thickness of 70 to 100 ft. At Wantage, on the other hand, a boring passed from Gault into Kimmeridge Clay with little or no Lower Greensand intervening, (7), but at Winkfield, (7), brown sand was bored into for 9 ft. below the Gault and believed to belong to the Lower Greensand. (See also Slough, p. 22, and Ottershaw in the table facing p. 134.)

In Oxfordshire the most extensive outcrop is that which borders the Thames from Clifton Hampden to Nuneham. At the former place it was proved in a well to exceed 37 feet in thickness and to rest on Kimmeridge Clay (8). At Shillingford it was proved to be 25 ft. thick (8). An outlier on Hurst Hill shows 20 ft. of Lower Greensand between Gault and Kimmeridge Clay, but on Boar's Hill the thickness appears to exceed 50 ft. (9).

Wealden.

The lower part of the Wealden formation is represented in Oxfordshire by the Shotover Sands. These ferruginous sands

and sand-rocks with their grey clay-bands occur as an outlier on Shotover Hill, and emerge from below Gault for some miles north of Thame. At Brill Common (Buckinghamshire) and Shotover Hill their estimated thickness is 45 to 50 ft., but the top is absent. In the main outcrop the part visible varies from 10 to 15 ft. in thickness according to the inequalities of the surface of Portland Stone on which they rest.

Oolitic.

Purbeck Beds.

In Berkshire the Purbeck Beds have not been recognised, and in most parts are certainly absent.

In Oxfordshire they are known only at Shotover, where they are represented by 4 ft. of clay and limestone, lying between the Shotover Sands and the Portland Beds (9).

Portland Beds.

In Berkshire Portland Beds are not known.

In Oxfordshire they emerge at intervals from beneath the Lower Greensand and Gault and form outliers. At Shotover they include an upper division about 40 to 50 ft. thick, of sand (a decalcified and silicified limestone) and about 4 ft. of clays with greenish sands and rubbly limestone; and a lower division about 60 ft. thick, of yellow and greenish sands with huge spheroidal concretionary masses, or further east of clayey sands about 25 ft. thick. The total thickness is estimated at rather more than 100 ft. South of Wheatley, however, a well in Horsepath Parish proved only 38¼ ft. of Portland Beds between the Shotover Sands and what was supposed to be Kimmeridge Clay.

Kimmeridge Clay.

The thickness of Kimmeridge Clay varies from 100 to 200 ft., but the whole formation is not always present under the Lower Greensand.

In Berkshire the following thicknesses have been proved:— Challow, 195½ ft.; Denchworth, 140 ft.; Wantage, 94 ft.?; Faringdon, 3 ft. At the last-named and probably also at Wantage, a part of the formation was missing in consequence of pre-Cretaceous denudation.

In Oxfordshire the thickness varies from 111½ ft. at Shillingford to 120 at Burcot, 94 at Culham, and in a northward direction to 111 at Marsh Baldon, and 180 at Cuddesdon. At Shillingford, Burcot and Culham, part of the formation may be missing from the cause above mentioned.

Corallian.

The Corallian Beds include an upper division of oolitic limestone (the Coral Rag) and a lower division of sand and calcareous or cherty sandstone (the Lower Calcareous Sandstone). They outcrop continuously across both counties.

In Berkshire they were traversed at Faringdon, and under 10½ ft. of Coral Rag (top absent) a thickness of 51 ft. of Lower

Calcareous Grit was proved. At Goosey the whole Corallian was 82 ft. thick, and at Wantage a boring penetrated for 77 ft. in Corallian, but the position of the junction with the Kimmeridge Clay was open to doubt.

In Oxfordshire the full thickness of Corallian was ascertained to be 79¾ ft. at Shillingford, more than 92 ft. at Culham, and more than 80 ft. at Cuddesdon.

Oxford Clay.

The Oxford Clay is a grey or pale-blue clay with bands of septaria; it forms a broad outcrop across Oxfordshire and occupies a part of Berkshire.

In Berkshire it was proved to exceed 112 ft. in thickness at Goosey (base not reached) and 258 ft. at Wytham (top absent) (7).

In Oxfordshire it was proved to exceed 265 ft. at Oxford and 155 ft. at Arncot, in each case the top being absent (8).

The full thickness therefore has not been traversed in any one boring, but it has been estimated to be 450 ft. (6).

Cornbrash.

This thin but constant band of irregular rubbly limestone with clay-partings does not appear at the surface in Berkshire but outcrops continuously across Oxfordshire.

In Berkshire the Cornbrash has been proved in one boring only, at Wytham, where it was 19 ft. thick (7).

In Oxfordshire it has been traversed in several borings and proved to vary from 10 ft. to 20 ft. 10 ins. in thickness (8).

Forest Marble.

The Forest Marble consists of alternations of irregular false-bedded and shelly limestone with clays.

In Berkshire the Forest Marble has been reached in the Wytham boring only, and was found to be 24½ ft. thick (7).

In Oxfordshire it has been proved by borings to be 18⅔ ft. thick at Arncot, 32⅔ at Oxford, 20½ at Kidlington, 38 at Islip, 21¼ at Bicester (8). Measurements at the outcrop give 12 to 19 ft. as the thickness (5).

Great Oolite and Upper Estuarine Series.

The Great Oolite includes an upper part of oolitic limestones with marls and a lower part of shelly limestones clays and sandy flags (Stonesfield Slate). The Upper Estuarine Series consists of variegated clays, sandy clays and irregular beds of limestone.

In Berkshire, in the Wytham boring, 96 ft. of strata attributed to the Great Oolite intervened between the Forest Marble and Inferior Oolite (7).

In Oxfordshire the Great Oolite series forms a wide and continuous outcrop. It has been bored through and its thickness proved at the following places (8):—Burford, 62½ ft. (top absent); Arncot, 56½ ft.; with Estuarine Series below to 41 ft. (base not reached); Oxford, 88 ft. (Upper Estuarine Series, 28½ ft.); Kidlington, 144½ ft. and clay (Estuarine Series?), 36 ft.; Bicester, 84½ ft., and Estuarine Beds, 4⅓ ft. (base not reached).

Inferior Oolite.

This subdivision consists chiefly of oolitic limestones, ferruginous and pebbly at the base. In Berkshire it has been seen only in the Wytham boring, where it was 35½ ft. thick.

In Oxfordshire it was proved at Burford to be 27⅔ ft. thick, and at Oxford 16⅓ ft., while at Kidlington a "hard rock" 7 ft. thick was supposed to represent it (8). Variations in thickness are due partly to the fact that the upper beds overlap the lower beds eastwards.

Northampton Sand.

This is a ferruginous sand and sand-rock which near Northampton represents the base of the Inferior Oolite and some underlying sands (Midford Sands).

In Oxfordshire it was supposed to have been recognised in a boring at Bicester where there were 17 ft. of loose sand below the Estuarine Beds, and at Mixbury where 5 ft. of "hard rock" intervened between the Estuarine Beds and the Upper Lias.

Liassic.

In Berkshire the Lias is the oldest rock as yet proved to exist. In the Wytham boring the Upper Lias was 14½ ft. thick, and the Middle and Lower Lias were penetrated for a distance of 170 ft. without reaching the base.

In Oxfordshire, in the Burford boring, the Upper Lias was 81½ ft. thick, the Middle Lias 98 ft. 1 in., and the Lower Lias 447 ft. 4 in., making a total of 626 ft. 11 ins. At Kidlington Lias, with possibly some Rhaetic beds, was bored into for a thickness of 133 ft. At Kingham a boring starting in the Upper Lias ended as supposed, in Lower Lias at a depth of 120 ft., proving the Middle Lias to be 64¼ ft. thick. At Mixbury, below Northampton Beds, 134 ft. of strata were assigned to the Upper Lias, and 36 ft. (base not reached) to the Middle Lias (8).

Triassic.

This formation has been proved in one spot only in Oxfordshire. At Burford below the Lias the boring traversed black shale, green marl and limestone for 91 ft., and then 375 ft. 11 ins. of variegated marls with gypsum, which rested on Coal Measures. The variegated marls may be safely assigned to the Keuper Marl; the black shale and green marl represent the Rhaetic but may include some Keuper Marl.

PRINCIPAL BORINGS IN BERKSHIRE AND OXFORDSHIRE. (*Thicknesses in feet.*)

	Winkfield.	Wellington.	Shillingford.	Wytham.	Oxford, City Brewery.	Oxford, St. Clement's Brewery.	Kidlington.	Witney.	Burford.
Bagshot Beds	—	192 (top absent)	—	—	—	—	—	—	—
London Clay	136 (top absent)	412	—	—	—	—	—	—	—
Reading Beds	78								
Chalk — Upper	337	to 130	—	—	—	—	—	—	—
Chalk — Middle	169	—	—	—	—	—	—	—	—
Chalk — Lower	219	—	—	—	—	—	—	—	—
Upper Greensand	31	—	—	—	—	—	—	—	—
Gault	264	—	144 (top absent)	—	—	—	—	—	—
Lower Greensand	to 9	—	25	—	—	—	—	—	—
Kimmeridge Clay	—	—	111½	—	—	—	—	—	—
Corallian — Upper	—	—	44½	—	—	—	—	—	—
Corallian — Lower	—	—	35¼	—	—	—	—	—	—
Oxford Clay	—	—	to 4½	258 (top absent)	210 (top absent)	265 (top absent)	2 (top absent)	—	—
Cornbrash	—	—	—	19	17		13	43	—
Forest Marble	—	—	—	24½	32⅔	155	20½		—
Great Oolite	—	—	—	96	88		144½	141½	62½ (top absent)
Upper Estuarine Series	—	—	—	—	28½		36		
Inferior Oolite	—	—	—	35½	16⅔	—	7	30	27⅔
Northampton Sand	—	—	—	—	—	—	—	—	—
Lias — Upper	—	—	—	14½	to 17	—	—		81½
Lias — Middle	—	—	—	to 170	—	—	to 133	to 55½	98
Lias — Lower	—	—	—		—	—			447⅓
Trias (Rhaetic and Keuper)	—	—	—	—	—	—	—	—	467
Palæozoic Rocks (Coal Measures)	—	—	—	—	—	—	—	—	to 226

BUCKINGHAMSHIRE.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial ..	Alluvium, Glacial Drifts, &c.	—
Eocene ...	London Clay	up to 200
	Reading Beds	36–78
Cretaceous	Upper Chalk, with the Chalk Rock at its base	330
	Middle Chalk, with the Melbourn Rock at its base	200–220
	Lower Chalk, including the Totternhoe Stone	180
	Upper Greensand	10–20
	Gault	200–248
	Lower Greensand	up to 250
	Wealden (Shotover Sands)	up to 45
Oolitic ...	Purbeck Beds	20–30
	Portland Beds	60
	Kimmeridge Clay	100
	Corallian (Ampthill Clay)	40–50
	Oxford Clay and Kellaways Beds ...	420
	Cornbrash	5–8
	Forest Marble and Great Oolite Clay...	13-40
	Great Oolite Limestone	15–25
	Upper Estuarine Series	15–33
	Lower Estuarine Series and Northampton Sands (Inferior Oolite) ...	8–27
Liassic ...	Upper Lias	120
	Proved in borings only :—	
Liassic ...	Middle Lias	to 22
	Lower Lias	240½
Palæozoic Rocks	... ...	—

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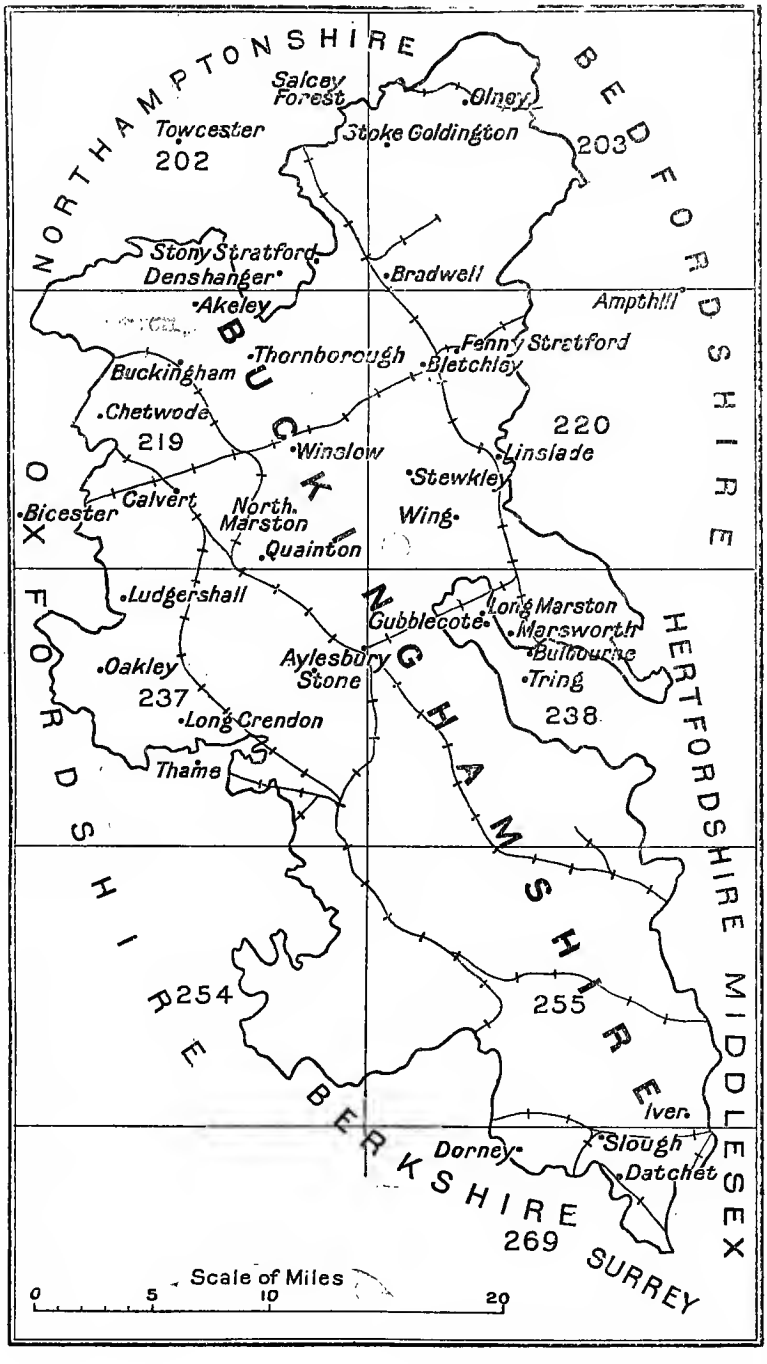
Superficial.

Of the superficial deposits the alluvium has been estimated to attain in places a thickness of 20 ft.; valley-gravels, 25 to 30 ft.; Glacial sands and gravels, 20 to 25 ft., and the chalky boulder-clay to range up to 50 ft. (10). The clay-with-flints rests on a surface

which has been eroded irregularly in great hollows or pipes 50 ft. deep or more (10). It therefore varies indefinitely in thickness, but may average about 30 ft.

FIG. 3. BUCKINGHAMSHIRE.



Eocene.

The London Clay is the newest formation in Buckinghamshire, but nowhere retains its original thickness. At Iver 103 ft. of the clay was proved in a well (2). There may be 200 ft. in the extreme south-east of the county.

The Reading Beds include dark grey and red mottled clays, variegated sands and pebble-beds. They vary in thickness from 36 to 78 ft. The following localities are arranged from north to south:—Slough, 36 to 54 ft.; Dorney Common, 78 ft.; Datchet, 78 ft. In each of these well-sections the full thickness of the Reading Beds was passed through (2).

Cretaceous.

Chalk.

The Chalk is divisible into Upper, Middle and Lower, or into zones characterised by assemblages of fossils.

The Lower Chalk has a thickness estimated at 180 ft. (4), the Middle Chalk, 200 to 220 ft. (4), and the Upper Chalk, 330 ft. (5).

The thicknesses of the zones have also been estimated as indicated in the subjoined table (4 and 5):—

Zones.		Thickness in feet.
Upper Chalk.	*Marsupites*	50
	Micraster coranguinum	200
	Micraster cortestudinarium	60
	Holaster planus	20
Middle Chalk.	*Terebratulina*	140-160
	Rhynchonella cuvieri	60
Lower Chalk.	*Actinocamax plenus*	3
	Holaster subglobosus	70–80
	Ammonites varians	100

The three well-known bands of hard chalk, the Totternhoe Stone, Melbourn Rock and Chalk Rock occur in Buckinghamshire, but the Totternhoe Stone is only feebly represented over much of the county. The Melbourn Rock, which occurs low down in the main escarpment of the Chiltern Hills, is a rock-like white chalk about 9 ft. thick. The Chalk Rock consists of three beds of cream-coloured limestone containing some glauconite grains, alternating with layers of nodules set in a matrix of soft chalk, and in all may be as much as 10 ft. thick.

Upper Greensand and Gault (Selbornian).

The Upper Greensand consists of greenish sands and marls with malmstone; it is seldom more than 10 or 12 ft. thick (3), but a boring at Slough proved 19 ft.[1] The Gault is a stiff dark-blue and pale calcareous clay which is divisible into an upper and a lower part, the former attaining a thickness of 70 ft. and the latter 145 ft. (3). In a boring at Thame Park (Oxon, just outside Bucks) there was 200 ft. of Gault and 230 ft. in another boring at Tring (Herts). A boring near Long Marston

[1] The Geology of the Country around Windsor and Chertsey, *Mem. Geol. Surv.* 1915, p. 104.

(Herts) proved 70 ft. of Upper Gault and 145 ft. of Lower Gault (3), while in two others, one at Marsworth and another at Bulbourne, the Gault was 238 ft. and 248 ft. respectively in thickness (3).

Lower Greensand.

This formation rests upon the denuded edges of the folded Jurassic rocks and comprises a variable group of sands, clays and fuller's earth. It occurs in disconnected patches below the Gault and is absent under a large part of the county. The greatest thickness attained has been estimated at 250 ft. (10).

Wealden.

Iron sands (Shotover Sands), containing fresh water shells and resting upon Purbeck or Portland Beds, form outliers upon Muswell Hill and Brill Common. They attain a thickness of about 45 ft. and are clearly remnants of an originally extensive deposit.

Oolitic.

Purbeck.

Purbeck Beds occur as outliers in the Vale of Aylesbury and comprise a series of marls, limestones and calcareous sands which vary in thickness from 20 to 30 ft. (8 and 10).

Portland Beds.

These extend from near Thame (in Oxfordshire) to Aylesbury, and also form outliers. They comprise about 33 ft. of sands and limestones in the upper part and about 20 ft., mostly of clay, in the lower part (10). At Long Crendon the thickness of the limestone has been estimated at 32 ft., and that of the Lower Portland Clay below at 30 ft.

Kimmeridge Clay.

The outcrop of this formation extends from the south-west across the county as far as the neighhourhood of Stewkley, where it is unconformably overstepped by the Gault. It presents its full development only in those spots where it is overlain by Portland Beds and then is estimated to reach 100 ft. Its extent to the south-east beneath the Cretaceous rocks is unknown.

Corallian.

These beds consist of a series of sands and calcareous sandstones and limestones, and in this form extend from Shabbington northwards through Oakley to Quainton (10). From Quainton north-eastwards the Corallian is rarely visible, and appears to be represented by the Ampthill Clay. This clay crops out near North Marston, also at Stewkley and to the south of Linslade. At Ampthill in Bedfordshire it is 61 ft. thick; in Buckinghamshire it is supposed to be 40 to 50 ft. (10).

Oxford Clay and Kellaways Beds.

The Oxford Clay including Kellaways Beds extends from near Ludgershall to Winslow and Fenny Stratford and is about 420 ft. thick. Most of the formation is clay, but some 20 or 30 ft. of sand and loam near the base represent the Kellaways Beds (10). A boring at Bletchley entered the upper part of the Oxford Clay at a depth of 9 ft. and ended as supposed at the base of the Kellaways at 410 ft.[1] At Calvert a boring starting in the Oxford Clay reached the base at a depth of 93 ft. (9).

Cornbrash.

This formation consists of rubbly limestone with marl or clay-bands, altogether from 5 to 8 ft. in thickness (7). A large outlying mass of Cornbrash with some Kellaways Beds occurs north of Buckingham beneath glacial drift.

Forest Marble and Great Oolite Clay.

The Forest Marble was represented in the Calvert boring by oolitic and shelly limestones and marly clays, with a total thickness of 38 ft. 9 ins.

The Great Oolite Clay is a formation of uncertain thickness and varying character. It consists at times of black, red or green clay, passing into tough blue shelly oolite (Forest Marble) which at Bicester (Oxfordshire) is about 18 ft. in thickness. The clay at Buckingham is some 15 ft. thick, but northwards it is less developed. At Bradwell there is 13 ft. of marly clay with sand and limestone (7 and 10).

Great Oolite Limestone.

The Great Oolite Limestone crops out over much of the northern part of the county and has been worked in many quarries which are but 10 to 15 ft. deep. In a pit at Bradwell about 16 ft. of limestone, and in the valley south-west of Thornborough about 21 ft., are exposed (7 and 10). The total thickness is believed to be about 25 ft.

Upper Estuarine Series.

The Upper Estuarine Series, consisting of black and variegated clays with white and brown sands, occurs at Stoke Goldington and along the borders of the Ouse to near Olney and is from 15 to 20 ft. in thickness. It has been proved in Salcey Forest, and at Denshanger and Stony Stratford (10), but in the country from Aynho to Towcester it is difficult to make any satisfactory divisions in the Great Oolite (7). The Great Oolite Clay, Limestone and Upper Estuarine Series are classed together with a united thickness of about 60 ft.

Lower Estuarine Series and Northampton Sands.

In Buckinghamshire these estuarine and marine groups occupy the place of the sands and oolitic limestones of the Cotswolds.

[1] *Geol. Mag.*, 1889, pp. 356-357.

The Lower Estuarine Series consists of loam and sand and appears to be about 8 ft. thick (10). The Northampton Sands are exposed only along the Ouse Valley and have been doubtfully met with in borings on the north-east of Stowe Park near Akeley and near Stony Stratford. A well north of Olney proved 27 ft. of these beds (7).

At Chetwode a boring proved alternations of rock and clay in thin beds to a depth of 230 ft. The boring commenced in Oxford Clay and ended in Middle Lias. None of the subdivisions of the Great or Inferior Oolite Series were recognisable.

The Calvert, Bletchley and Chetwode borings prove that there is a considerable area in North Bucks, where the Oolitic rocks older than the Oxford Clay are not normally developed.

Liassic.

The Upper Lias is the oldest formation exposed in Buckinghamshire and is estimated to reach 120 ft. at a maximum (10). At Calvert it was believed to be absent, but the Lower Lias to be represented (p. 22).

PRINCIPAL BORINGS IN BUCKINGHAMSHIRE.

Thicknesses in feet.

	Datchet.	Horlick's Malted Milk, Slough.	Wing.	Marsworth.	Gubblecote near Long Marston.	Near Akeley.	Stony Stratford (town).	Calvert.	Bletchley.	Stone.
Valley Drift	7½ / 19	— / 24½	— / —	— / —	— / —	— / 25	— / 9	— / —	— / —	— / —
London Clay	Top absent. 20	—	—	—	—	—	—	—	—	—
Reading Beds	78	54	—	—	—	—	—	—	—	—
Chalk	Touched.	757½	Top absent. 80	Top absent. 36	—	—	—	—	—	—
Upper Greensand } Selbornian	—	185½	220	240	Top absent. 215	—	—	—	—	—
Gault ... }										
Lower Greensand	—	to 13	to 26	to 94	to 10	—	—	—	—	—
Purbeck Beds	—	—	—	—	—	—	—	—	—	—
Portland Beds	—	—	—	—	—	—	—	—	—	20
Kimmeridge Clay	—	—	—	—	—	—	—	—	—	
Corallian	—	—	—	—	—	—	—	—	—	
Oxford Clay and Kellaways Beds.	—	—	—	—	—	Top absent. 65	—	Top absent. 93	Top absent. 410	500
Cornbrash	—	—	—	—	—	—	—	—	—	—
Forest Marble and Great Oolite Clay.	—	—	—	—	—	18 ?	15	39	—	—
Great Oolite Limestone ...	—	—	—	—	—			59½	—	to 30
Upper Estuarine Series ...	—	—	—	—	—	33	16	7½*	—	—
Lower Estuarine Series and Northampton Sands.	—	—	—	—	—	to 9	1	—	—	—
Upper Lias	—	—	—	—	—	—	57	—	—	—
Middle Lias	—	—	—	—	—	—	to 22	—	—	—
Lower Lias	—	—	—	—	—	—	—	240½	—	—
Palæozoic Rocks, &c. ...	—	—	—	—	—	—	—	to 954½	Touched.	—

* Chipping Norton Limestone.

CAMBRIDGESHIRE AND HUNTINGDONSHIRE.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Alluvium	0–30
	Glacial Deposits	0–180[1]
Cretaceous	Chalk ... Upper	to 237
	Chalk ... Middle	210–230
	Chalk ... Lower	160–170
	Gault	70–242
	Lower Greensand	12–120
Oolitic	Kimmeridge Clay	100–142
	Corallian (Ampthill Clay)	26–150
	Oxford Clay with Kellaways Rock	400–700(?)
	Cornbrash	0–15
	Great Oolite Clay	5–40
	Great Oolite Limestone	10–17
	Upper Estuarine Series	30–40
	Lincolnshire Limestone, 0 to upwards of 5 ft.	
	Lower Estuarine Series	
	Northampton Sands	about 17
	Proved in borings only :—	
Liassic	Upper Lias	85–101
	Middle and Lower Lias	to 265

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SUPERFICIAL.

Alluvium.

The alluvial deposits find their widest development in the Fen Country. Their average thickness lies between 20 and 30 ft. and they consist of alternations of peat, silt and gravel. Those of the rivers Cam and Ouse have an average thickness of about 10 ft. with a maximum of 30 ft.

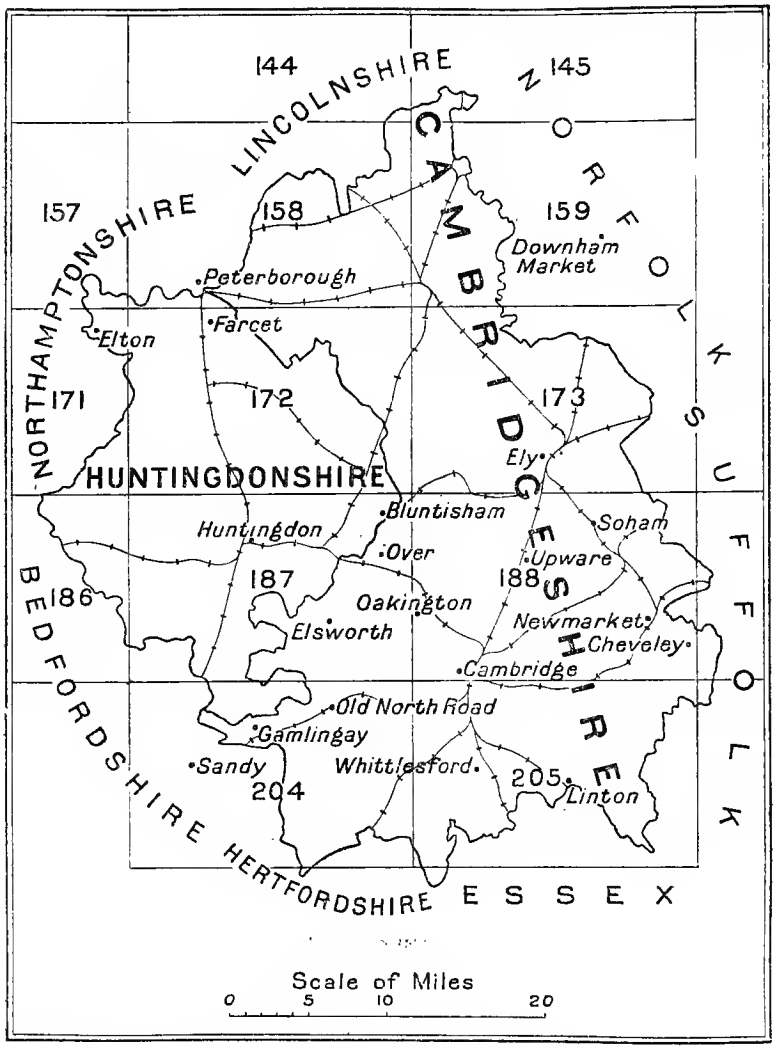
Glacial.

Of these variable deposits the most important member, the chalky boulder clay, ranges up to 180 ft. in thickness. This was proved near Caxton and at Old North Road Station (9).

[1] Not including some exceptional thicknesses found in buried channels.

A boring recently made at Whittlesford[1] has proved that the Drift extends there to a depth of more than 455 ft. and more than 335 ft. below sea-level. This deep hollow forms a continuation of the channel described on p. 54.

FIG. 4. CAMBRIDGESHIRE AND HUNTINGDONSHIRE.



CRETACEOUS.

Chalk.

The Upper Chalk occupies a belt of drift-covered country on the eastern border of Cambridgeshire from Newmarket to Linton. The formation is nowhere complete, but 237 ft. is recorded from a boring at Cheveley on the chalk-plateau above Newmarket.[2]

[1] Summary of Progress for 1914, *Mem. Geol. Surv.*, 1915, p. 65.
[2] *Rep. Brit. Assoc.* for 1914, p. 269.

The Middle Chalk, which includes all the beds from the base of the Chalk Rock to the base of the Melbourn Rock, has a maximum thickness of 230 ft. (6, 9), but is believed to thin slightly northwards.

The thickness of the Lower Chalk near Cambridge is 166 ft. (9). This subdivision also thins out north-eastwards. The attenuation is well shown in the Chalk Marl, which in south Cambridgeshire is 60 ft. thick, while at Cambridge it is 30 ft. and in north Norfolk only 19 ft. (8).

At the base of the Chalk Marl lies the 'Cambridge Greensand,' a band which is never more than a few feet in thickness, but which yields evidence of local unconformity.

Gault.

The greatest thickness of Gault is recorded at Newmarket, where 242 ft. were passed through in a boring. At Cambridge the Gault is 150 ft. thick (8), but it thins northwards, so that at Soham it is only 90 ft. (8), while in the northern part of Norfolk it is replaced by 4 ft. of Red Chalk (9). Over a great part of Cambridgeshire the Upper Gault has been removed by contemporaneous erosion to form the 'Cambridge Greensand.'

Lower Greensand.

The Lower Greensand at Sandy, three miles outside the S.W. boundary of Cambridgeshire, is more than 120 ft. thick (8), but much less over most of the area. At Upware there are only 12 ft. of sands (9). The Lower Greensand, unlike the overlying beds, thickens again northwards to 170 ft. in Norfolk (9).

Oolitic.

Kimmeridge Clay.

There is a marked unconformity between the Cretaceous and Jurassic rocks, in consequence of which the Lower Greensand rests upon the Oxford Clay in the south-west. The Ampthill and Kimmeridge Clays come on in a north-easterly direction. The Kimmeridge Clay, which is the highest Jurassic formation in these counties, forms a narrow outcrop by Oakington and Elsworth and runs in a north-easterly direction to the Isle of Ely. Here it spreads out and forms the base of the Isle, beneath a covering of Lower Greensand. The thickness is about 100 ft., of which only 15 ft. belong to the Upper Kimmeridgian (4). At Downham Market (Norfolk) a boring passed through 187 ft. of Kimmeridgian without reaching the base (4).

Corallian.

Below the Kimmeridgian comes a variable series referred to the Corallian. In the south at Gamlingay it is represented by the Ampthill Clay, which at Over has a thickness of 150 ft. (8). At Elsworth it is in part represented by a calcareous bed known as the Elsworth rock. Near Stretham Ferry the total thickness of the Corallian is 45 ft. (4), while at Upware it is represented by a coral-limestone, probably about 54 ft. thick (9).

Oxford Clay.

The Oxford Clay occupies much of the surface of Huntingdonshire. The total thickness has never been proved, but Penning and Jukes-Browne estimated it as 700 ft., while H. B. Woodward considered 500 ft. a more likely figure (4). The basal bed of the Oxford Clay, the Kellaways Rock, is from 13 to 17 ft. thick near Peterborough.

Cornbrash and Oolitic Rocks below the Cornbrash.

The Cornbrash is found in well-sinkings over the northern part of Huntingdonshire. It ranges up to 15 ft.

The amount of information available regarding the underlying beds is small and the thicknesses given in the table on p. 23 are approximate. The Lincolnshire Limestone was found at Elton but seems to be generally absent.

Liassic.

An unpublished boring at Farcet proved 101 ft. of Upper Lias, while a Peterborough boring proved 85 ft. of Upper Lias and 265 ft. of Middle and Lower Lias (3).

CHESHIRE.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium and Peat	—
	Glacial deposits, to more than ...	300
Liassic		to 300
Triassic ...	Keuper Marls	2,000–3,000
	Keuper Waterstones	200
	Keuper Basement Beds	180–314
	Upper Mottled Sandstone	500–800
	Pebble Beds	750–950
	Lower Mottled Sandstone	500–1,280
Permian		0–1,500
Carboniferous		—

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SUPERFICIAL.

Alluvium and Peat.

There are many peat-mosses in Cheshire. The largest in the eastern part of the county is Dane's Moss, near Macclesfield, with an area of 300 acres. From 10 to 15 ft. of peat have been removed from the west side for fuel, and a depth of 40 ft. is said to have been proved in the deepest parts (9, pp. 108-109). Peat-mosses occur also near Congleton, Alsager and elsewhere, but in some cases they have been almost completely dug away. In the Chester district mere-basins with peat occur. 'Many of these, which were filled with water within the memory of old inhabitants [1882], are now dry.' (4, p. 30.) The largest of these meres in the Delamere district is Oakmere; and Blake Mere the largest peat-moss.

Glacial.

Glacial drift covers most of the low ground in Cheshire. It consists mostly of boulder-clay, but patches of sand and gravel of variable extent appear through the clay in all parts of the area.

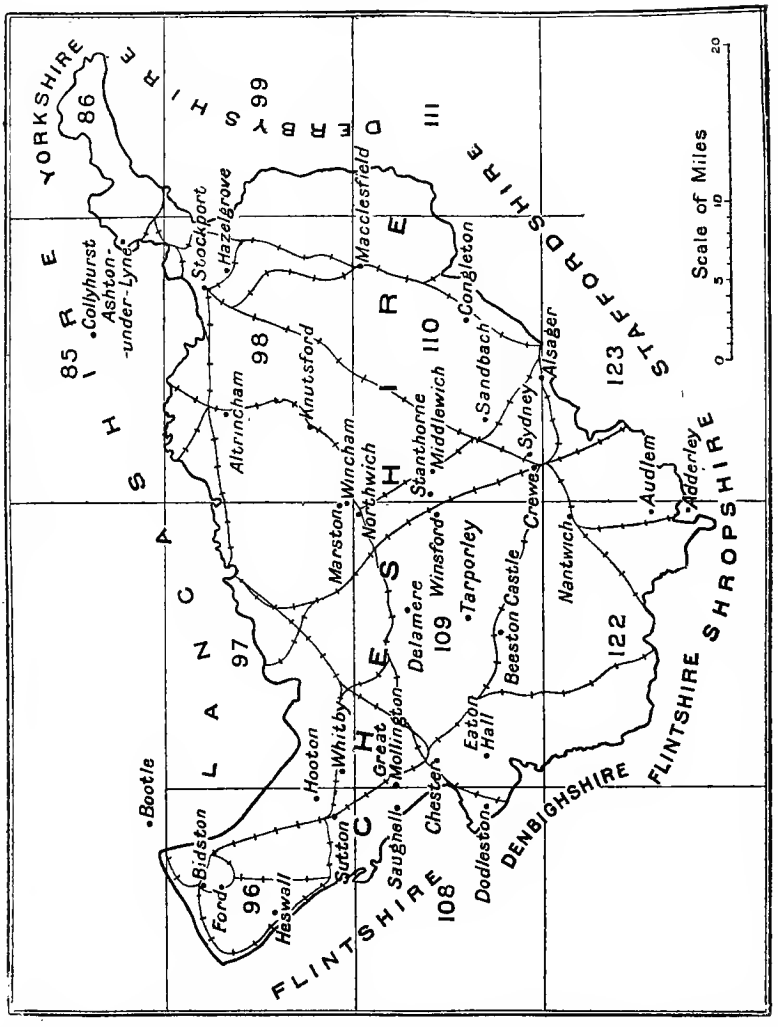

Fig. 5. Cheshire.

The thickness of these deposits is largely dependent upon the unevenness of the rock-surface on which they rest. Old valleys in the sandstone, filled with drift, are sometimes struck in borings. A boring at Sydney showed that the drift there is over 320 ft. thick and descends to at least 160 ft. below present sea-level, while to the west an outcrop of Keuper Marls shows that the surface rises at least 200 ft. within two miles (9, pp. 68, 104). Borings have been made in the estuary of the Dee through the superficial deposits in search of coal, and have proved, in many cases, a great thickness of post-glacial and glacial material over the rock. Most of these borings are in Flintshire, but that at Dodleston is within the Cheshire boundary and shows that the pre-glacial valley has a depth of 90 ft. below present sea-level at that place (5, pp. 151-153 and 221-222). Around Macclesfield the maximum thickness of drift recorded is in a bore at the County Asylum, where 220 ft. of boulder-clay and sand rest on

the Upper Mottled Sandstone. At the brewery near the railway-bridge, Sutton, the Pebble Beds were reached after going through 75 ft. of drift. At the North Cheshire Brewery, Macclesfield, the drift was 148 ft. thick, but only 44 ft. at Park Green Well (9, pp. 60 and 66).[1] Around Northwich and Middlewich many borings have been made through the drift into the Keuper Marls for salt, and the following thicknesses, in feet, have been found near the places indicated:—Marston, 31 ft. 9 ins.; Wincham, 33, 44 and 12 ft. in adjacent borings; Winsford, 304½; Stanthorne, 65; Cledford Bridge, Middlewich, 48; Sandbach, 75 ft. At Hooton, in Wirral, 169 ft. of drift was penetrated before the surface of the rock was reached at 62 ft. below Ordnance Datum.[2] At Saughall 60 ft., and one mile north-east of Great Mollington 80 ft. of drift, overlie the Trias. In many cases borings quite close together show considerable differences in the thickness of the drift.

Liassic.

An outlier, of Lower Lias chiefly, presumably with Rhaetic beds at its base, covers a considerable area in Shropshire, but just comes within the Cheshire boundary near Audlem. It is mostly covered with drift, 80 to 90 ft. thick in places. The black shales were supposed to be 'coal shales,' and borings were made in many places, but the fossils proved them to be Lias with lignite. At Adderley (Shropshire) a boring went through 300 ft. of this black shale into Keuper Marls (6, pp. 180-183).

Triassic.

The Red Marls, the uppermost formation of the Keuper, generally thickly drift-covered, occupy a large area in Cheshire, extending over the central parts of the county, around Northwich, Knutsford, Middlewich, Congleton, Crewe and Nantwich. There is no definite information as to their thickness, but various estimates ranging from 2,000 to 3,000 ft. have been made.

At Marston a boring showed 1,763 ft. 11 ins. of Red Marls resting on Waterstones (7). The Maypole Dairy Company's boring near Congleton Station, starting in drift, did not reach the bottom of the marls at a depth of 960 ft. (9, p. 112), and another boring at Winsford, after traversing 304 ft. of drift, passed through 1,190½ ft. of marls without reaching their base.

The Lower Keuper Sandstone, being much harder than the marls, outcrops much more frequently through the drift, and forms bold escarpments. The Waterstones and Basement Beds are included here in Lower Keuper Sandstone. Near Chester and to the north-west the Waterstones have been computed to have a thickness of 200 ft., and the Basement Beds, with Frodsham Beds, 180 to 250 ft. (4, pp. 9 and 13). In the Altrincham (1, p. 3) and Stockport (2, p. 38) areas the Lower Keuper Sandstone has been estimated to have a thickness of 450 ft. An abstract of the

[1] See also J. D. Sainter. 'Scientific Rambles round Macclesfield,' 8vo, Macclesfield, 1878, pp. 53-55.

[2] T. Mellard Reade. 'The Buried Valley of the Mersey,' *Proc. Liverpool Geol. Soc.*, vol. ii, 1873, p. 53.

boring at Marston (7), mentioned above, is given in the table on p. 31. It shows the greatest recorded thickness of Lower Keuper Sandstone.

The Bunter of Cheshire has been divided into Upper Mottled Sandstone, Pebble Beds and Lower Mottled Sandstone. In the north-east the Pebble Beds rest directly on Permian strata.

The thicknesses of these divisions are variable and deep borings in the north-west have proved them to be greater than was expected. Around Stockport the thicknesses given are:—Pebble Beds, 750 ft.; Upper Mottled Sandstone, 600 ft. (2, p. 37). In the Chester area the Lower Mottled Sandstone is stated to vary greatly, up to a maximum of 500 ft. (4, p. 2). The Pebble Beds were estimated at 600 ft., 'but may probably be more' (4, p. 3). The Upper Mottled Sandstone was estimated to be from 500 to 800 ft. in thickness (4, p. 5). In the north-west of the area the Pebble Beds thicken considerably. The Heswall bore,[1] which commenced about 400 ft. below the top of the Upper Mottled Sandstone, passed through 108 ft. of that division, 934 ft. of Pebble Beds, and 1,272 ft. of soft red sandstone before reaching Coal Measures. At Bootle, on the Lancashire side of the Mersey, the Pebble Beds were proved to have a thickness of more than 1,200 ft. (3:—for 1878, pp. 10, 13-15; for 1879, p. 110; for 1880, p. 1). At Bidston, too, a great thickness of Pebble Beds was stated to be present, but the records of the bore were not clear (8, p. 298).

Permian.

These beds consist of a marly series at the top with a sandy series below. The sandy beds have a development around Stockport which has been estimated to be as much as 1,500 ft. (2, p. 33). The marls, correlated with fossiliferous marls at Collyhurst (Lancashire), have a thickness of 134 ft. east of Stockport.[2] At Hazelgrove a deep boring proved 913 ft. of Permian Beds.[3]

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[1] Summary of Progress for 1913 (*Mem. Geol. Surv.*), 1914, p. 97.

[2] *Rep. Brit. Assoc.* for 1895, p. 770.

[3] *Final Report, Royal Commission on Coal Supplies*, 1905, Part IX, Appendix ii, p. 13. [Here also a review of thickness of beds above the coal in the Cheshire basin.] See also *Trans. Manchester Geol. Soc.*, vol. xxii, 1893, pp. 452-458.

PRINCIPAL BORINGS IN CHESHIRE.

Thicknesses in feet.

	Ford, near Bidston.	Heswall.	Whitby.	Marston.	Wincham.	Hazelgrove, near Stockport.	Eaton Hall Waterworks.	Beeston Castle Pumping Station, Tarporley.	Winsford.	Winsford, Ways Green.	Northwich, Manor Farm.	Northwich, Irlam Works.	Stanthorne.	Middlewich, Cledford Bridge.	Sandbach.	Crewe, Sydney.	Macclesfield, County Asylum.	Macclesfield, North Cheshire Brewery.
Boulder Clay	46	60	20	32	44	80	20	56	304	216	62	—	65	48	75	to 320	220	148
Glacial Sand and Gravel ...	16		70				—	2				8						
Keuper—																		
Red Marl	454	—	—	1764	to 125	—	—	—	to 1190½	to 75	to 132	to 450	to 395	to 142½	to 238	—	—	—
Lower Keuper Sandstone ...	to 244 Fault	—	—	708	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bunter—																		
Upper Mottled Sandstone ...	to 33	108	—	to 106	—	—	—	Red Sst.	—	—	—	—	—	—	—	—	to 124	—
Pebble Beds	—	934	*t'ched*	—	—	30	to 327	to 52	—	—	—	—	—	—	—	—	—	*t'ched*
Lower Mottled Sandstone ...	—	1272	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
Permian—																		
Marls and Sandstones... ...	—	—	—	—	—	913	—	—	—	—	—	—	—	—	—	—	—	—
Carboniferous, Upper	—	to 988	—	—	—	to 602	—	—	—	—	—	—	—	—	—	—	—	—

CUMBERLAND AND WESTMORLAND.

Table of Strata.

		Thickness in feet.
Superficial ..	Alluvium	—
	Glacial	up to 186
Liassic ...	Lower Lias	up to 210
Triassic ...	Stanwix Shales	up to 23
	Kirklinton Sandstone	400
	Gypseous Shales	900
	St. Bees Sandstone	2,000
	Gypseous Shales	0–250
Permian ...	Magnesian Limestone	1–30
	Plant Beds (Hilton Shales)	150
	Penrith Sandstone and Brockram ...	1,500
Carboniferous and older rocks		—

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SUPERFICIAL.

Alluvium.

Broad alluvial flats with peat-mosses form the low ground bordering the Solway. On the coast near Silloth blown sand covers wide areas and in places reaches a thickness of 30 ft.

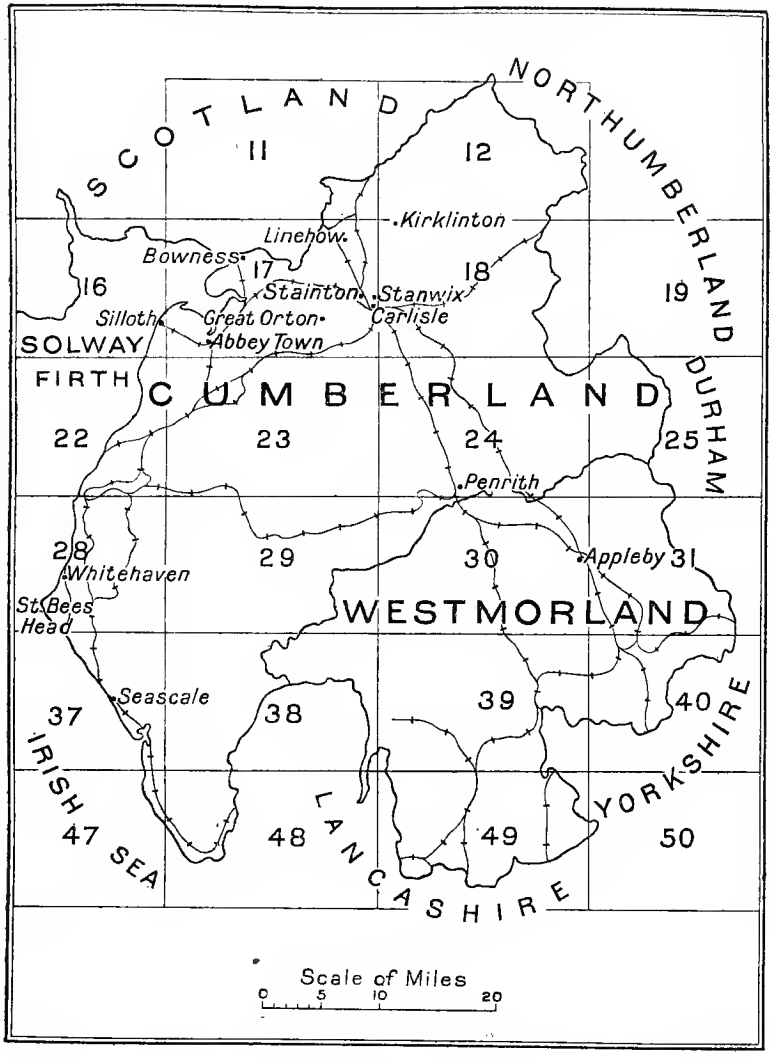
Glacial.

The Glacial drifts cover much of the low-lying ground. They may be divided into esker-gravel and sand and a boulder-clay with earthy gravels. The esker-gravel varies in thickness up to 100 ft., while the greatest proved thickness of the boulder-clay is 186 ft. This was found in a boring near Abbey Town (4).

LIASSIC.

The Lower Lias forms a small outlier at Great Orton. A boring has proved 210 ft. of shales and limestones belonging to the zone of *Psiloceras* [*Ammonites*] *planorbis* (4), and possibly including some Rhaetic Beds.

FIG. 6. CUMBERLAND AND WESTMORLAND.



TRIASSIC.

Rhaetic beds have not been proved to exist in this area, and the highest Triassic rocks known to occur are found in the Carlisle basin, where they have been termed the Stanwix Shales. Their maximum proved thickness is 23 ft.

Beneath the Stanwix Shales lie the red and white Kirklinton Sandstones, with a thickness of not less than 400 ft. (4). Between the Kirklinton and St. Bees Sandstones some gypseous shales, which have only been found in borings, are supposed to intervene (1 and 4). A part of these was traversed in the Abbey Town boring (p. 35); they are estimated to reach a thickness of

900 ft. They must vary rapidly in thickness, for they are absent between Carlisle and Kirklinton.

The St. Bees Sandstone is the most conspicuous member of the Triassic group of this area. It consists of micaceous red sandstones, of which the thickness in the north of the Eden Valley is estimated at 1,500 to 2,000 ft. Northwards and eastwards from Carlisle the St. Bees Sandstone overlaps all the underlying red rocks and rests upon the Carboniferous.

At the base of the St. Bees Sandstone, in the Carlisle basin and near St. Bees Head, there crops out another group of gypseous shales which are estimated as having a thickness of 250 ft. (5).

At Seascale, on the coast to the west of the Lake District, the St. Bees Sandstone has been bored into for 2,000 ft. without being bottomed.[1] In a later account Prof. Gregory gives the total depth of the boring as 3,200 ft., and tentatively suggests that the boring may have been in Kirklinton Sandstone down to a depth of 2,073 ft. and in St. Bees Sandstone for the remaining 1,127 ft.[2]

Permian.

The Magnesian Limestone and its associated plant-beds (Hilton Shales) form the upper, and the Penrith Sandstone and Brockrams the lower group of the Permian.

In the Whitehaven area the Permian Brockram occurs in faulted strips in the coal-field. In places it reaches 180 ft. in thickness.

The Magnesian Limestone is found along the southern edge of the coal-field and has a maximum thickness of 30 ft. in the west at St. Bees Head, but thins to 1 or 2 ft. in the east.

In the Eden Valley the Magnesian Limestone is only a foot or two thick, but at this horizon are the Hilton plant-bearing shales with gypsum, which have an estimated maximum thickness of 150 ft. (3).

The Penrith Sandstone is a red sandstone without mica, in which respect it differs from the St. Bees Sandstone. In parts of this sandstone secondary quartz has been deposited in crystalline continuity with the original rounded sand-grains. The Brockrams occur chiefly in the southern part of the Eden Valley, where there is one at the base and another in the middle of the Penrith Sandstone. They consist of angular blocks of rock, mainly Carboniferous Limestone, firmly cemented together.

Estimates of the thickness of the Penrith Sandstone group near Appleby vary from 1,000 ft. to 1,500 ft. (3). In the north of Cumberland this group is much reduced in thickness and is locally absent (2).

[1] Summary of Progress for 1909 (*Mem. Geol. Surv.*), 1910, p. 5.
[2] *Geol. Mag.*, 1915, p. 146.

Some Borings in Cumberland and Westmorland.
Thicknesses in feet.

	Seascale.	Abbey Town.	Bowness.	Great Orton.	Stainton.	Linehow.
Alluvium	—	12½	—	—	7	—
Glacial	—	186	41	18	—	36
Lias	—	—	—	210	—	—
Trias — Stanwix Shales ...	—	—	—	—	23 to 394	—
Trias — Kirklinton Sandstone	—	—	—	—		171
Trias — Upper Gypseous Shales	— to 2,000	734 to 87	367 touched	to 132		— to 69
Trias — St. Bees Sandstone						

DERBYSHIRE.

Table of Strata.

		Thickness. in feet.
Superficial ..	Alluvium	15–30
	Glacial	up to 70
Triassic ...	Keuper Marl	up to 380
	Lower Keuper Sandstone ...	50–150
	Bunter Pebble Beds	up to 1,000
	Lower Mottled Sandstone	impersistent
Permian ...	Magnesian Limestone	60–140
	Basement Beds	36–88
Carboniferous		—

Authorities.

1. The Triassic and Permian rocks of the Midland Counties of England, *Mem. Geol. Surv.*, 1869.
2. The Geology of the Country between Atherstone and Charnwood Forest, *ib.*, 1900.
3. The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch and Loughborough, *ib.*, 1905.
4. H. H. Arnold Bemrose. The Victoria History of the Counties of England, Derbyshire, 1905.
5. The Geology of the Leicestershire and South Derbyshire Coalfield, *Mem. Geol. Surv.*, 1907.
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Superficial.

Alluvium.

The alluvial deposits cover a considerable area alongside the Trent and appear to extend to a depth of 20 to 30 ft. Thus a boring at Sawley showed the Trent gravels to be 25 ft. thick, whilst four borings across the southern border of the county near Burton-on-Trent showed respectively 19 ft. 2 in. of sand, clay, peat and gravel, 24 ft. of gravel in another, 30 ft. of gravel in a third, and 31 ft. of gravel in the fourth (3). Alluvial deposits, but of smaller extent, occur in the Derwent, Erewash and Rother valleys.

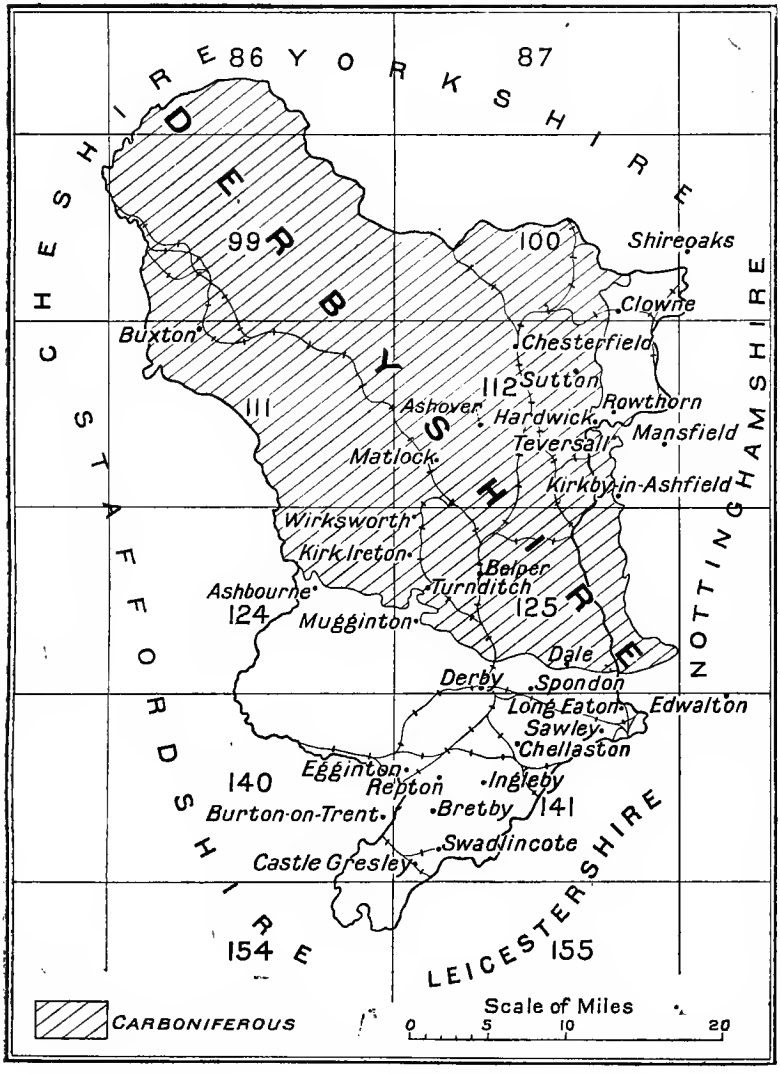
Valley gravels are also found at various levels above the Trent and the Derwent (7).

Glacial.

In the neighbourhood of Matlock and Ashover some patches of boulder-clay occur (7), and near Ashbourne a well sunk at Spital Hill showed 70 ft. of drift overlying Keuper Marl. Further to the east at Blackwall, near Kirk Ireton, a section shows 25 ft. of glacial sand and gravel (4). Near Derby a well sunk at Spondon two miles from the town showed upwards of 30 ft. of boulder-clay, while four miles south-east of Derby, at

Chellaston Hill, a boring passed through 40 ft. of boulder-clay into chalky sand 6 ft. deep. This was underlain by 10 ft. of loamy sand and gravel and rested on Keuper Marl (4). In the extreme south of the county also the ground is overlain by glacial deposits, which, however, are not so thick and important here as in the Soar Valley and Loughborough district in Leicestershire to the south-east. A boring made near Burton-on-Trent on the 400-ft. contour proved 16 ft. of boulder-clay (3).

FIG. 7. DERBYSHIRE.



Triassic.

Along the southern and eastern margins of the Derby and Nottingham Coalfield the Trias does not much exceed 800 ft. in thickness. The groups represented are:—

Trias ... ... { Keuper Marl.
Keuper Waterstones with a basal conglomerate.
Bunter Pebble Beds.
Lower Mottled Sandstone.

Keuper.

The Keuper Marl with thin sandstones and bands of gypsum occupies a much larger proportion of the surface of South Derbyshire than the other Triassic rocks. Nowhere, however, in the county is the full thickness developed. The marl rests conformably upon and graduates down into the sandstones below, but as the Charnwood Hills are approached it overlaps all the underlying Triassic rocks till it comes to rest on the old rocks themselves.

Across the eastern border of the county 389 ft. of Keuper Marl was bored through at Edwalton, while at Sawley the same formation was traversed for 112 ft. in a boring which started well below its top (3). A boring at Burton-on-Trent in Staffordshire showed 297 ft. of Keuper Marl; another in Derbyshire, but close to Burton, at Egginton Common, showed 99 ft. of Keuper Marl with gypsum. In none of these cases, however, is the full thickness of the Keuper Marl shown (3). It reaches 1,000 ft. in parts of Staffordshire, but is likely to be less in Derbyshire.

The Lower Keuper Sandstones or 'Waterstones' consist of beds of white and pink sandstone with marl-bands, having at their base beds of breccia. They appear to vary in thickness from 50 to 100 ft. but to thicken westward to 150 ft. or more (5).

Bunter.

The Bunter is but feebly represented at the outcrop, its total thickness falling short of 100 ft. in the neighbourhood of Dale, but each member gradually widening eastward and also westward though not to so marked an extent. The Pebble Beds are persistent over the area, while the Lower Mottled Sandstone is often absent (6).

The maximum thickness of the Pebble Beds in the area around Kirk Ireton, Turnditch and Mugginton is about 130 ft., whilst in the district south of Belper the whole of the Bunter seldom exceeds 30 to 40 ft. In the neighbourhood of Ashbourne the Pebble Beds are stated to be at least 120 ft. thick. The variations in the thickness of the Bunter are attributable to the irregularity of the pre-Triassic floor on which it was spread. In the neighbourhood of the Millstone Grit (6), the irregularity is especially pronounced.

Further south, in the neighbourhood of Repton and Ingleby, the Pebble Beds attain a thickness of nearly 200 ft. In the extreme south of the county, where they form the only representative of the Bunter, they have probably a maximum thickness of 1,000 ft., 600 ft. being found in a boring at Chilcote (5), but

over most of the ground they are less well developed, and towards the east the gradually thin away altogether, on the margins of the Leicester coalfield.

Permian.

The principal outcrop of Permian rocks occurs in a narrow north and south strip near the eastern boundary of Derbyshire. In this county the Lower Magnesian Limestone, with the basement beds, alone is present. The basement beds usually consist of a breccia with overlying grey marls and thin limestones, representing the Marl Slates. Close to the county boundary at Kirkby-in-Ashfield in Nottinghamshire they are 4 to 5 ft., and the marls and thin limestones from 15 to 20 ft. thick. In the Sherwood Colliery at Mansfield the breccia is 8 ft. and the grey marl series 88 ft. thick. Where it enters Derbyshire north of Teversall the series is seldom over 30 ft. (7). About 12 ft. of it is seen in the Rowthorn railway cutting, and at Hardwick Old Hall a deep trench showed magnesian limestone passing down into 15 ft. of thin limestones and marl-partings, the total thickness of the basement beds here being 25 ft. (7). Further north still, at Clowne, the basement beds appear to be represented by 12 to 18 ft. of quicksands overlain by 15 to 20 ft. of grey marls (7). From Clowne northwards to the Yorkshire border the base of the Permian consists of 'quicksands.' At Shireoaks the 'Sandrock' at the base of the Permian is 1 ft. 8 ins. and the marly series 54 ft. thick (7).

The Magnesian Limestone where it enters Derbyshire is about 100 ft. thick. Thus it is 142 ft. at Sherwood Colliery, Mansfield, and about 65 ft. around King's Mill, Sutton, and 103 ft. at Shireoaks Colliery (7).

In the extreme south of Derbyshire some marls and breccias which have been provisionally classed as Permian cover a small area. About 50 ft. represents their maximum development, and they apparently occur along hollows in the underlying Carboniferous rocks.

At Castle Gresley they are about 24 ft. thick, while at Swadlincote the breccias and marls of the so-called Permian average 15 ft. At Bretby Colliery they are represented by $6\frac{1}{2}$ ft., and further south by 8 ft., of breccia.

For records of borings near to the borders of Derbyshire reference should be made to the tables relating to Leicestershire and Nottinghamshire.

DEVON AND CORNWALL.

Table of Strata.

		Thickness in feet.
Superficial ..	Alluvium, Gravels, &c....	—
Pliocene ...	... ...	—
Oligocene ...	Bovey Beds	up to 456
Eocene ...	Blackdown and Haldon Gravels ...	up to 40
Cretaceous	Upper Chalk	up to 90
	Middle Chalk	100–236
	Lower Chalk	2–60
	Upper Greensand } Selbornian ...	65–200
	Gault ... ... }	
Liassic ...	Lower Lias	105
Triassic ...	Rhaetic	up to 45
	Keuper Marls	1,300
	Upper Sandstone	up to 302
	Pebble Beds	80
Permian ...	Permian Marls	200–800
	Lower Sandstone and Breccias ...	up to 900
	Clay with Breccia (Watcombe Clay) ...	20–700
Carboniferous and older rocks		—

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7. ,, ,, near Sidmouth and Lyme Regis, *Mem. Geol. Surv.*, 2nd Ed., 1911.
8. Geology of the Country around Newton Abbot, *Mem. Geol. Surv.*, 1913.
9. W. A. E. Ussher. Victoria History of the Counties of England, Devon, 1906.
10. ,, Geology in the Field, *Geol. Assoc.*, 1910, p. 859.

SUPERFICIAL.

Tracts of gravel, angular detritus (or 'head') and alluvium flank most of the rivers in Devon, and raised beaches occur around the coast. The Alluvium fills deep channels and attains a thickness up to 80 ft. both in the north and south of the county (5 to 8). Deposits of blown sand and talus ('head') overlie the raised beaches and may average 12 ft. in thickness, but in North Devon reach 50 ft. Angular detritus, where it fills up hollows, may often be 40 ft. thick, but more usually averages about 10 to 12 ft.

The terrace-gravels lie principally at two levels, about 50 and 100 ft. respectively above the modern rivers. The higher gravel in the Axe Valley is 60 ft. thick, but this is exceptional, the average being 15 ft. (5 to 8).

FIG. 8. DEVONSHIRE.

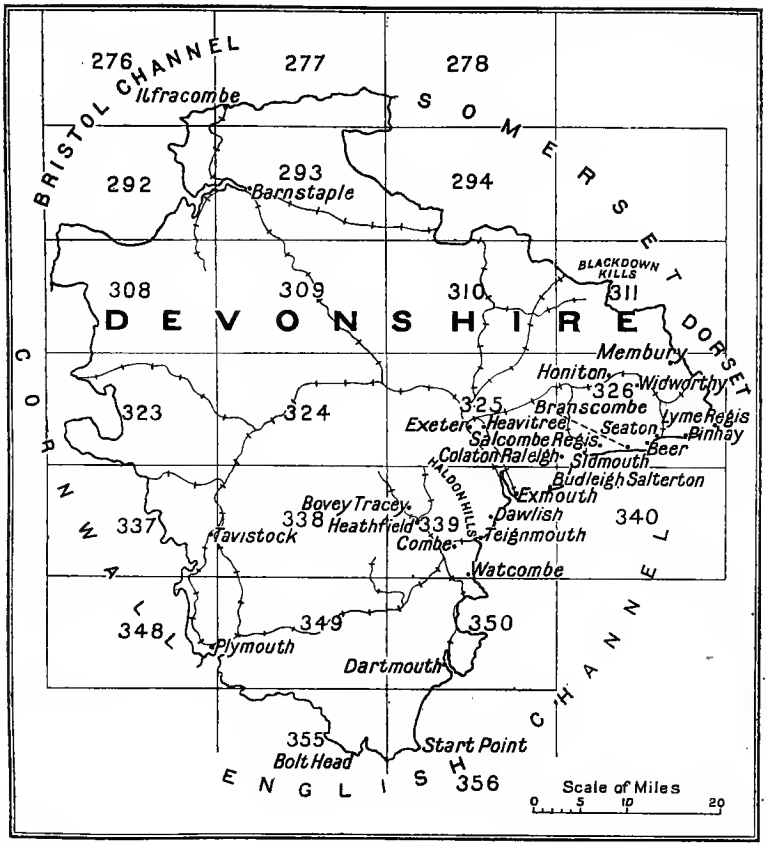
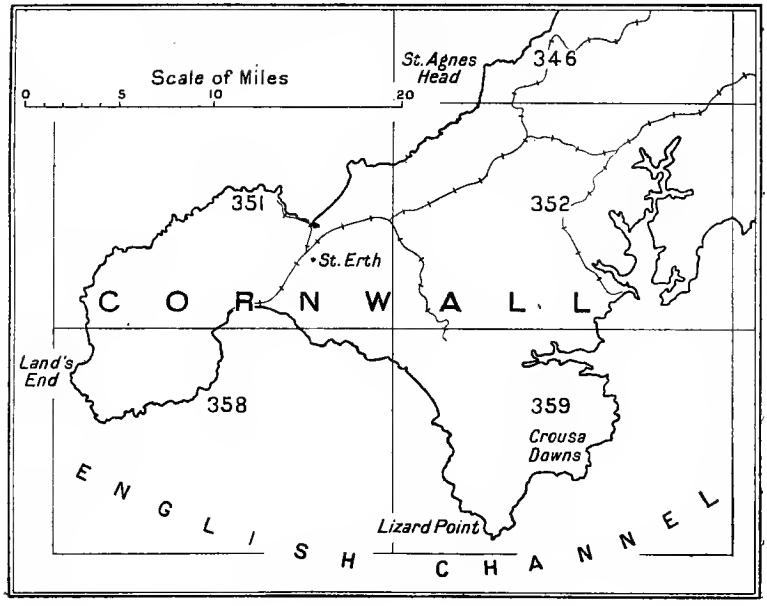


FIG. 9. CORNWALL.



Pliocene.

Small relics of Pliocene Beds occur near St. Erth in the Land's End district, at Crousa Downs in the Lizard district and at St. Agnes Head on the north coast of Cornwall. The deposits include sand, gravel and clay, and in places exceed 20 ft. in thickness.

Oligocene.

The clays and sands with lignite at Bovey Tracey are probably of Oligocene age (8). Their total thickness is unknown, but a boring at Heathfield proved 456 ft. of clay, sand and lignite (8) without reaching the base.

Eocene.

Widespread deposits of uncertain age, possibly Eocene, and consisting of angular and subangular detritus associated with either clay or sand, cover the upland plains. They maintain a fairly uniform thickness of some twenty feet (7). The Eocene gravel of Haldon Hills is 40 ft. thick in places (8).

Cretaceous.

Chalk.

On the coast of Devon there are two principal outliers of Chalk, one between Lyme Regis (Dorset) and Seaton, and the other between Seaton and Branscombe. Lower Middle and Upper Chalk are in part represented, but zones above that of *Micraster cortestudinarium* are absent. There is a remarkable variation in the thicknesses of the strata assigned to some of the zones, and especially to that of *Terebratulina*. The changes observable in the cliff are indicated in the following table. The localities read from west to east (7):—

Chief Stratigraphical Divisions.		Zones.	Branscombe and Beer.	Whitecliff.	Pinhay.
			feet.	feet.	feet.
Upper Chalk.	Chalk with flints ...	*Micraster cortestudinarium.*	30	20+	50+
	Chalk with flints and phosphatic nodules.	*Holaster planus* ...	60	34	40
Middle Chalk.	Chalk with flints ...	*Terebratulina* ...	90 to 156	70	72
	Hard and soft nodular chalk with flints locally in upper part Beer Stone, and hard quartziferous chalk.	*Rhynchonella cuvieri*	20–80	28	60
Lower Chalk.	Calcareous sandstone and arenaceous chalk with quartz-grains.	*Holaster subglobosus* and *Ammonites (Schloenbachia) varians.*	14–30	2–3	2–3

Inland the Lower and Middle Chalk are found in the faulted tract between Offwell and Widworthy east of Honiton; and also

at Membury. At Membury there seems to be from 50 to 60 ft. of Lower Chalk and probably not more than 80 ft. of Middle Chalk (9).

In Devon parts of the Chalk assume the characters of sandstones and limestones. The change is especially noticeable in the lower part of the formation, for the three hard bands known as Chalk Rock, Melbourn Rock and Totternhoe Stone all assume a sandy facies, while the Lower Chalk consists at its base of calcareous sandstone of variable thickness which is overlain by a bed of quartziferous limestone. These arenaceous beds are exposed on the coast from Lyme Regis nearly as far as Sidmouth, and inland at Wilmington near Widworthy. At the base of the Middle Chalk there is a bed of freestone (Beer Stone) which consists of granular limestone almost entirely composed of comminuted fragments of *Inoceramus* shells. There is no regular bed of Melbourn Rock, but a bed of hard yellowish nodules is probably its equivalent (3).

Selbornian.

These beds form the bold uplands of East Devon, the best sections being exhibited in the cliffs near and east of Sidmouth. They are divisible into two main groups, the Chert Beds and the Greensands.

This series has an average thickness of 200 ft. which is fairly constant in East Devon. It thins further west, especially in its lower division. At Black Ven in Dorset the thickness of the greensand under some chert beds is 119 ft. Further west at Whitecliff the chert beds and greensand are 68 and 88 ft. respectively. Below Beer Head the total thickness is some 156 ft., while still further west beyond Branscombe it is about 170 ft. (7). At Peak Hill west of Sidmouth the lower beds are about 20 ft. thinner (7), the total estimated thickness being about 65 ft. (2). At Great Haldon Hills the beds appear to be 65 ft. thick and at Little Haldon about 90 ft., a well at a house on the hill proving that thickness.

In the inland districts of Devon there are few localities where the formation is complete. The lower or Blackdown sands have been estimated at from 80 to 100 ft., and in places the base of the sand is 200 ft. below the summit of the ridges and there is no reason to suppose the total thickness is less than along the coast (2).

The sections proved in the shafts of the tunnel on the London and South-Western Railway at Honiton show that the basement beds increase in thickness from east to west, but this is due to the surface of the underlying Red Marl being uneven. The five shafts from east to west penetrated the following thicknesses of greensand:—179, 221, 213, 169 and 91 ft., the variation being partly due to change of surface level (2).

LIASSIC.

The Lower Lias is exposed in the cliffs east of Seaton and there consists of blue limestone thickening eastwards from 70 to 85 ft., covered by 16 ft. of clay and shale, and this by indurated grey

marl, giving in all a thickness of 105 ft. (1 and 9). There is reason for believing that the stone-beds of Lyme Regis, in the neighbouring part of Dorset, diminish in thickness towards the north. The only available information as to the thickness of the Lias in Devon is derived from the coast-sections.

Triassic.

Rhaetic.

The coast-sections east of Seaton show that the White Lias is 25 ft. and the Black Shales 20 ft. thick (7).

New Red Series.

The underlying Keuper Marls have been estimated at 1,300 ft. in thickness, the uppermost 35 ft. being grey and the remainder chiefly red. A boring for coal near Lyme Regis penetrated 1,130 ft. of these marls without reaching their base (7 and 9). The sandstones which underlie the marls rise into the cliffs at Sidmouth and thence after a brief interval extend westwards to Budleigh Salterton. A borehole for the water supply of Exeter, made at Dotton Lane near Colaton Raleigh, started in sandstones at an estimated depth of 100 ft. from their junction with the overlying marls, and continued in them to a depth of 302 ft. Thence to the bottom, a further distance of 36 ft., the boring was in pebble-beds (7).

The Budleigh Salterton Pebble Beds are perhaps as much as 80 ft. on the coast but appear to diminish inland (7).

Permian.

The Permian beds of Devon consist of a series of breccias and sandstones overlain by marls, all most variable in thickness but showing a remarkable attenuation towards Exeter.

The marls extend along the coast from Exmouth to near Budleigh Salterton and northwards to the borders of Somerset. On the coast they can scarcely be less than 800 ft. thick but they thin northward to 200 ft. near Somerset (9).

The Lower Sandstone and Breccia have an estimated thickness of 450 ft. (8), while 332 ft. of the underlying boulder-breccia was proved in a boring at Combe, near Teignmouth, without the base being reached (8).

There can scarcely be less than 500 ft. of the Watcombe breccia on the coast, but it appears to diminish rapidly northwards to 20 or 30 ft. near the Teign estuary (9). A boring at Heavitree commenced in this series and encountered 697 ft. of sandstone and marl.

The Watcombe Clays have a restricted distribution on the coast and are probably nowhere more than 150 ft. thick (9).

DORSET.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial ..	Alluvium, Valley Gravel	—
	Plateau Gravel, Clay with Flints ...	—
Pliocene ...	Elephant Bed of Dewlish	—
Oligocene ...	Creech Barrow Limestone	—
Eocene ...	Bagshot Beds	to 400
	London Clay	100–250
	Reading Beds	70–100
Cretaceous ..	Chalk (Upper, Middle and Lower) ...	up to 1,320
	Upper Greensand and Gault (Selbornian)	up to 170
	Lower Greensand	0–198
	Wealden	up to 2,350
Oolitic ...	Purbeck Beds	189–395
	Portland Beds	average about 260
	Kimmeridge Clay	900 to about 1,200
	Corallian	120–216
	Oxford Clay with Kellaways Beds ...	about 500
	Cornbrash	about 30
	Forest Marble	80–130
	Fuller's Earth (Fullonian)	about 150
	Inferior Oolite	15–45
	Midford Sand	135–150
Liassic ...	Lias (Upper, Middle and Lower) ...	about 900

Proved in borings only :—

Triassic ...	Rhaetic Beds	60
	Keuper Marl ...	proved to be more than 1,168

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1. Jurassic Rocks of Britain, *Mem. Geol. Surv.*, vol. iii, 1893.
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6. ,, ,, *ib.*, vol. iii, 1904.
7. Geology of the Country around Ringwood, *ib.*, 1902.
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9. ,, ,, Dorchester, *ib.*, 1899.
10. Geology of the Isle of Purbeck and Weymouth, *ib.*, 1898.
11. Geology of the Country near Sidmouth and Lyme Regis, *ib.*, 2nd Ed., 1911.

Superficial.

Plateau Gravel abounds in south-east Dorset at various levels from 330 ft. downwards. The higher outliers consist mainly of angular flints, the lower of much subangular material derived from the Eocene deposits. There are good sections at Moreton Station in the gravel of the lower plateaus. It is there about 8 ft. thick, which appears to be about the average (9). Clay-with-flints is found on the higher parts of the Chalk, especially near Dorchester, but it is seldom more than 5 ft. thick (9).

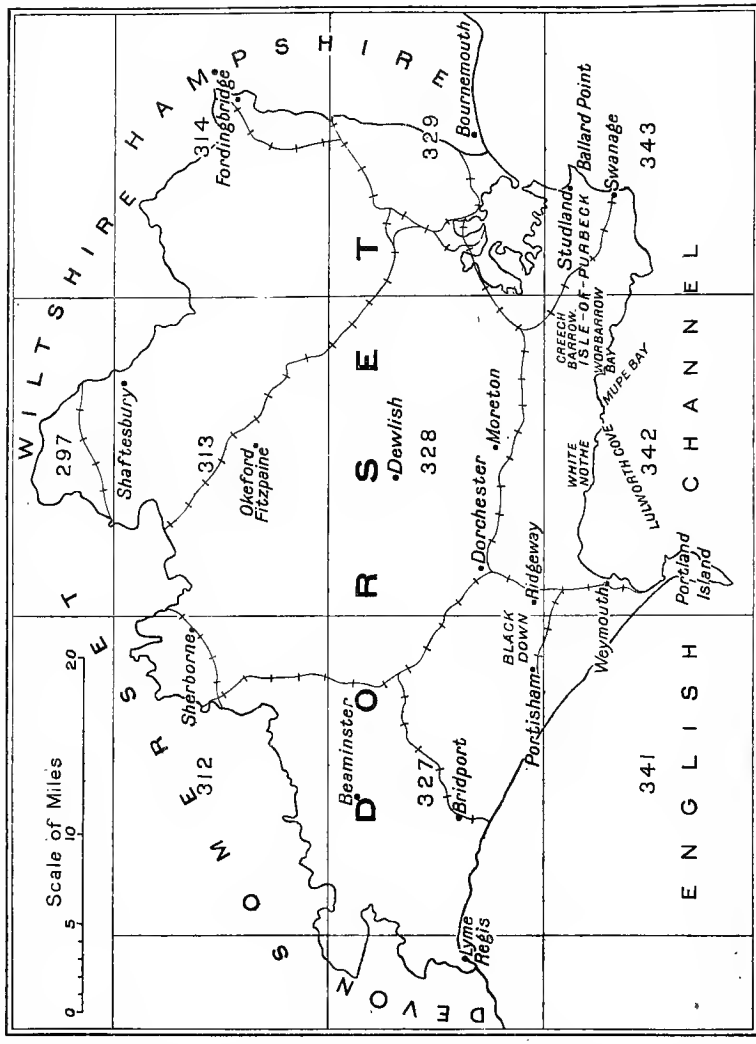

FIG. 10. DORSET.

PLIOCENE.

The only Pliocene deposit known in Dorset occupies a cleft or fissure in the Chalk at Dewlish.

OLIGOCENE.

The existence of a limestone, probably of Oligocene age, on Creech Barrow has been demonstrated by Messrs. W. H. Hudleston, *Geol. Mag.* for 1903, pp. 149 and 197, and H. Keeping *ib.* 1909, p. 555.

EOCENE.

Bagshot Beds.

The Bagshot Beds in this county mainly consist of sand and gravel with seams of pipe-clay and lenticular masses of carbonaceous loam or clay containing fossil leaves. Westward the

deposits become coarser and more gravelly. The top of the Bagshot Beds has not been seen, but a thickness of several hundred feet is believed to be attained (8).

London Clay.

This formation, as developed in Dorset, consists largely of sand or sandy loam (9). It is partly overlapped westwards by Bagshot Beds. At Fordingbridge, just within the Hampshire border, it was found, in a well-section, to be 118 ft. thick and also to contain many seams of clay with septarian nodules (7). Nearer Dorchester it has thinned out to less than 100 ft. (9); but further south, at Studland and near Lulworth, it was estimated to be 250 ft. and 150 ft. respectively, in both cases, however, the sharp folding of the strata making an estimate difficult (10).

Reading Beds.

Near Dorchester the Reading Beds contain a certain amount of the characteristic red-mottled clay, but mostly consist of coarse sand and fine gravel. In a well-section at Fordingbridge their thickness was found to be 73 ft. 6 in. (7). In the Bournemouth district it is said to be about 70 ft. (8), and near Dorchester 70 or 80 ft. (9). At Studland it has been estimated at 100 ft., but the beds there are distorted by folding.

Cretaceous.

Chalk.

The Chalk shows a marked attenuation westwards in all its subdivisions, and is, moreover, partly overlapped in the same direction by the Tertiary Beds.

In South Dorset we have a series of estimates ranging from Swanage through the Isle of Purbeck, but the disturbed and crushed condition of the strata renders precise measurement impossible. Near Swanage these estimates give, for the Upper Chalk, 1,049 ft., for the Middle Chalk, 128 ft., for the Lower Chalk, 143 ft. Thence westwards to White Nothe, at the west end of the 'Isle,' the measurements show Upper Chalk, 956 ft., Middle Chalk, 134 ft., and Lower Chalk, about 80 ft. Still further west, on Blackdown, the overlap by the Tertiary Beds is so marked that there are only 300 to 500 ft. left of the Upper Chalk (10).

In North Dorset the thickness of the Upper Chalk is about 950 ft. (6), while that of the Middle Chalk ranges from 100 ft. to 70 or 80 ft., the attenuation being westwards. The Lower Chalk varies from 180 ft. near Shaftesbury to 80 or 90 ft. westwards, chiefly through a diminution in the thickness of the Chalk Marl (5).

Upper Greensand and Gault (Selbornian).

The Gault Clay passes gradually westwards into a glauconitic sandy clay or silt, which is indistinguishable lithologically from the Upper Greensand. While therefore the united thickness of the two members of the Selbornian remains fairly constant, with a slight tendency to thicken westwards, the relative thicknesses of sand and clay change greatly. In South Dorset they vary as

follows:—Near Ballard Point, sand 65 ft., clay 91 ft.; at Worbarrow, sand becoming loamy below, 124 ft., clay 46 ft.; at Lulworth, sand with some clay in the lower part, 129 ft.; at White Nothe, sand 102 ft., sandy clay and clay 48 ft. In West Dorset the united thicknesses amount to 160 or 170 ft. (10).

Between Shillington and Okeford Fitzpaine the clay is about 60 ft. thick, but no trace of it has been seen at Beaminster, where the sand is about 100 ft. thick (4). The Gault rests with a pronounced unconformity upon all the older rocks in turn.

Lower Greensand.

The upper subdivision of the Lower Greensand consists chiefly of sand, but includes a dark clay with selenite in the upper part and is interlaminated with clay in the lower part. The lower subdivision consists of reddish clay (Atherfield Clay) with some sandstone and with a sandy base. Both subdivisions thin away westwards. The sands not infrequently throw out strong springs of chalybeate water. In South Dorset, near Swanage, the upper sandy subdivision is 149 ft. and the lower clayey subdivision 49 ft. thick. In Worbarrow Bay these thicknesses are reduced respectively to 104 ft. and 32 ft., while in Mupe Bay the thickness of the whole formation is not more than 66 ft. The Lower Greensand is not seen again in Dorset west of this bay (10).

In North Dorset the Lower Greensand crops out from beneath the Gault near Shaftesbury and Okeford Fitzpaine. Three miles south of Shaftesbury it consists of fine sand with thin layers of coarse quartz-sand in the upper part, and is estimated to be between 30 and 40 ft. thick (A. J. Jukes-Browne, *Geol. Mag.* for 1891, p. 456). At Okeford Fitzpaine it is represented by a few feet of sand between the Gault and the Kimmeridge Clay (R. B. Newton, *Geol. Mag.* for 1896, p. 198).

Wealden Beds.

This formation consists in Dorset of extremely variable sands and pebbly grits, irregularly interbedded with red or mottled clays. At the eastern end of the Isle of Purbeck, it includes, at its top, about 35 ft. of fossiliferous shales.

The Wealden Beds are thickest in the eastern part of the county. Westwards they thin rapidly, and at the same time become increasingly coarser in grain. At Swanage their thickness is estimated at 2,350 ft., and at Worbarrow Bay, at 1,237 ft. (10). In Lulworth Cove the strata are so distorted that no reliable estimate of thickness is possible.

Oolitic.

Purbeck Beds.

In South Dorset the Upper Purbeck Beds consist of clays and shales with thin limestones, which pass insensibly upwards into the Wealden clays. The Middle Purbeck also are largely made up of shales and alum-shales but include many courses of limestone. The Lower Purbeck, which near Swanage consist largely of clays, with limestone in the lower part only, contain more limestone towards the west. Carbonate of lime ('beef'), with

sulphates of lime and of alumina, occurs in many beds. All three subdivisions thin away somewhat rapidly westwards; they are overstepped by the Gault near Portisham, and are not seen again in Dorset, but they re-appear in Wiltshire. Near Swanage the thicknesses of the Upper, Middle and Lower Purbeck Beds respectively are:—60 ft., 166 ft. and 169 ft.; at Worbarrow, 49 ft., 89 ft. and 152 ft.; at Ridgway, 49 ft., 52 ft. and 88 ft. (Vert. Sects. of the Geol. Survey, Sheet 22).

Portland Beds.

In South Dorset these consist of a massive limestone in the upper part and of loamy calcareous sands in the lower part, the latter becoming more clayey downwards so as to graduate into the underlying Kimmeridge Clay. The limestone as developed near Swanage is about 100 ft. thick and includes bands and nodules of black chert in the lower half. The Portland Sand is about 100 to 120 ft. thick. Westwards the limestone thins gradually to about 70 or 80 ft. in Portland, and the sands probably share in the attenuation, but their base is extremely indefinite (10).

In North Dorset the Portland Beds are not seen at the surface, but they crop out in the Vale of Wardour (Wiltshire, pp. 143, 144).

Kimmeridge Clay.

This formation consists chiefly of shale with a few thin layers of argillaceous limestone. Some of the shale is bituminous and one band has been worked under the name of 'Kimmeridge Coal.' The fact that the Kimmeridge Clay graduates up into the Portland Sand has led to apparent discrepancies in the statements of its thickness. Allowing a thickness of 100 to 120 ft. for the Portland Sand, the thickness of the Kimmeridge Clay may be estimated to be about 900 ft. in the Isle of Purbeck, and to lie between 1,100 and 1,300 ft. north of Weymouth (10).

In North and West Dorset the Kimmeridge Clay forms a broad outcrop, but its thickness has never been ascertained.

Corallian.

These beds reach their greatest development, so far as regards England, in the neighbourhood of Weymouth.

They include the following strata in descending order:—

	S. Dorset. feet.	N. Dorset (3). feet.
Thin limestone, locally converted into haematite and calcareous grit	about 12	15
Clays with calcareous bands, &c., and calcareous sandstones	about 20	22
Clays	25	
Reddish calcareous grits	14	58
Oolitic limestone and marl	60	
Laminated sands with calcareous 'doggers'	10	25
Sandy clays	40	
Calcareous grits, &c.	35	

The aggregate thickness may be taken as being 200 ft. in South Dorset and not more than 120 ft. in North Dorset.

Oxford Clay with Kellaways Beds.

The Oxford Clay consists of clay and shale with septarian nodules. The Kellaways Beds, at its base, are represented near Weymouth by thin bands of calcareous sandstone of variable thickness. The total thickness of the group in Dorset may be taken at about 500 ft. (3).

Cornbrash.

This formation though thin is constant in occurrence. It consists of rubbly and nodular limestones, not oolitic, separated by layers of clay or shale, and makes a small but characteristic scarp in the landscape. It ranges from 30 to 40 ft. in thickness in South Dorset (10) and from 20 to 25 ft. in North Dorset (2).

Forest Marble.

The Forest Marble consists of grey clays with false-bedded oolitic, shelly limestones, irregularly interstratified but the limestones predominating towards the middle. The base of the Forest Marble is arbitrary, so that estimates of thickness in South Dorset have varied from 80 to upwards of 130 ft. (2 and 10). In North Dorset the thickness is estimated at 130 ft. (2).

Fullonian.

This formation in Dorset consists chiefly of clay with some lenticular bands composed of oyster-shells.

The Fuller's Earth Rock, consisting of earthy limestones which separate the Upper and Lower Fuller's Earth Clays, has not been distinguished in South Dorset, but has been traced from North Dorset northwards to near Bath (Somerset).

In South Dorset the Fullonian attain their maximum development, and have been estimated to be 150 ft. thick (2).

In North Dorset the Fuller's Earth Rock has been seen to a thickness of 34 ft., and the Lower Fuller's Earth Clay to a thickness of nearly 50 ft. (2).

Inferior Oolite and Midford Sands.

The Inferior Oolite in Dorset consists mainly of bands of oolitic, earthy or sandy limestone, while the Midford Sands are composed of micaceous yellow sands, with bands or nodular masses of calcareous sandstone. On the coast, near Bridport, the total thickness of the Inferior Oolite was found to be about 15 ft., but in a boring at Castleton, Sherborne, about 45 ft. were assigned to this formation. In the same boring the total thickness of the Midford Sands was 135 ft., but a thickness of 150 ft. or more is said to be attained in some parts of Dorset (2).

LIASSIC.

The Upper Lias consists mainly of bluish-grey clay and shale, with nodules of argillaceous limestone, the lowest bands being

pale earthy limestones and marls or clays. The Middle Lias is chiefly composed of micaceous sands with 'Doggers,' micaceous marl and clay with nodules of grey earthy limestone, sandy limestones, and calcareous sandstones. The Lower Lias consists mostly of clays or shales and limestones. In South Dorset, from observations made on the sea-cliffs, it is estimated that the Upper Lias is about 70 ft. thick, the Middle Lias 345 ft.; and the Lower Lias 485 ft.—total about 900 ft. (1).

Triassic.

Rhaetic.

These beds, as shown by a boring at Lyme Regis (11), consist of white limestones and marls in the upper part, with a thickness of 28 ft., and of dark shales and occasional thin limestones in the lower part, with a thickness of 32 ft.

Keuper Marl.

In the Lyme Regis boring referred to above, the marls were penetrated to a thickness of 1,168 ft. without reaching their base. The uppermost 81 feet were grey and green marls, part of which is included by some authors in the Rhaetic group, while the remainder consisted of red and green marls with gypsum (11).

ESSEX.

Table of Strata exposed or proved in borings.

		Thickness in feet.
Superficial ..	Alluvium	0–70
	River Gravel	0–40
	Glacial Drift	0–more than 340
Pliocene ...	Crag	a few feet.
Eocene ...	Bagshot Beds	to 45
	London Clay	to 532
	Oldhaven Beds, 0–25 feet	30–181
	Woolwich and Reading Beds, 20–60 feet.	
	Thanet Sand, 0–100 feet	
Cretaceous	Upper, Middle and Lower Chalk ...	—
	Proved in borings only :—	
Cretaceous	Upper Chalk, 420½ feet	647–890
	Middle Chalk, 228½ feet	
	Lower Chalk, 173½ feet	
	Upper Greensand and Gault	61–200
	Lower Greensand (supposed).. ...	—
Oolitic ...	Clays of doubtful age	—
Palæozoic Rocks	... ...	—

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SUPERFICIAL.

Alluvium and River Gravel.

The deposits of clay, silt, and peat classed under the head of Alluvium acquire an unusual importance owing to their wide extent in the Essex marshes.

On the north shore of the Thames as far east as Purfleet, the Alluvium averages about 15 ft. in thickness, and rests upon about 20 ft. of gravel (ballast). It includes beds of peat formed by the growth of aquatic plants and by the drifting of wood (3 and 5).

At Tilbury there are more numerous alternations of clay and peat, and the total thickness reaches 50 ft. in places, while the underlying gravel may be 10 or 20 ft. (5).

Near Corringham, to the west of Canvey Island, the Alluvium includes a bed of peat 2½ to 3 ft. thick, and extends to a depth of more than 50 ft. Dark gravel with a thickness up to 27½ ft. underlies it (5).

In Canvey Island mud and sand extend to a maximum depth of 80 ft., but the underlying gravel in such cases is absent. In the same neighbourhood the sand is 30 ft. and the gravel 40 ft. thick (5).

On Foulness Island the Alluvium consists of brown and dark sand, and extends to a depth of 70 ft. as a maximum. Shingle and ballast intervene in places between it and the Tertiary Beds (5).

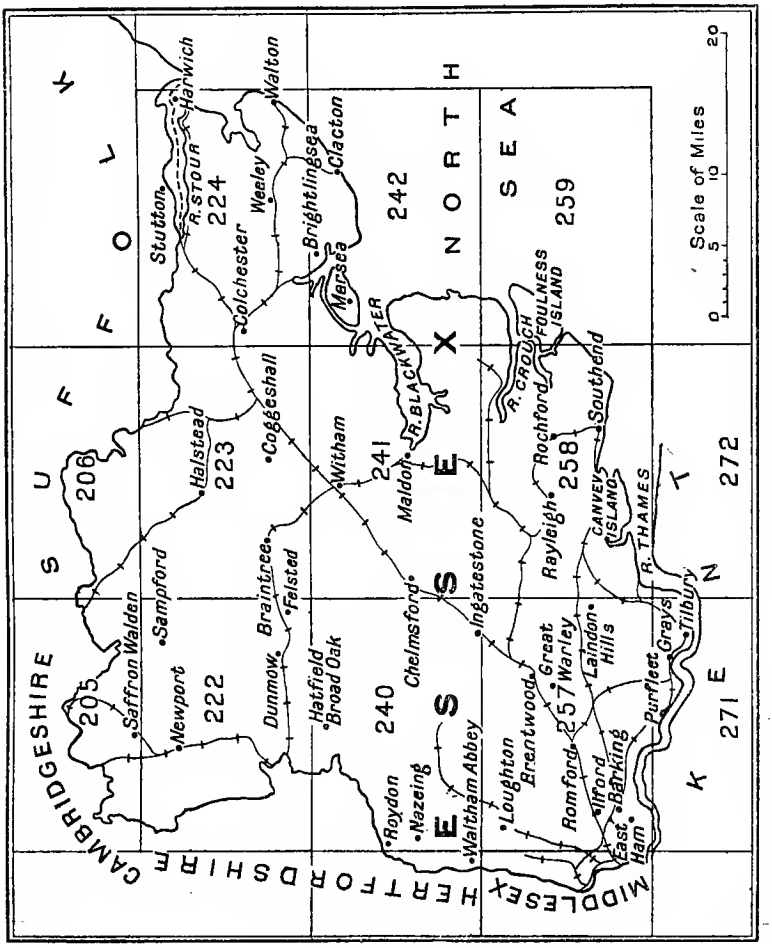

FIG. 11. ESSEX.

Glacial.

A great sheet of boulder clay which stretches across Cambridgeshire and Suffolk enters Essex and extends, in outliers, as far south as Brentwood. The Drift ranges up to a thickness of considerably more than 100 ft., but in such cases consists of boulder-clay with sand and gravel, in varying sequence. Gravel may form the bulk and boulder-clay may occur in subordinate bands, but over a large part of the county boulder-clay occurs at the surface and is underlain by sand and gravel.

The following are some of the most notable thicknesses met with in wells (5):—

In the one-inch Map 205[1]:—Ashdon, 57 feet; Chrishall, not bottomed at 72; Great Chesterford, mostly sand and gravel 156; Littlebury, loam, clay and sand, not bottomed at 218; Little Chesterford, boulder-clay 126 on 6 feet of gravel.

In the one-inch Map 206[1]:—Birdbrook, boulder-clay 75 feet on sand 43 feet; Foxearth, clay and gravel 51; Henny, sand and gravel 76; Ovington, boulder-clay 104 on sand 21; Tilbury-juxta-Clare, boulder-clay (supposed) 95 feet.

In the one-inch Map 222[1]:—Arkesdon, brown clay 105; Debden, brown and blue clay 73½; Debden Cross, boulder-clay 126 on sand and gravel 75; Elsenham, clay, gravel and sand 86; Great Hallingbury, clay and sand not bottomed at 128 feet; Great Saling, boulder-clay 12 on sand and gravel 63; Newport, clay, loam and sand not bottomed at 340 feet in one well, but bottomed at 185 feet in another; Quendon, clay, gravel and sand to 79½; Radwinter, clay and gravel 91; Rickling, boulder-clay 22 on gravel and sand 61; Stansted Mountfitchet, gravel 67; Takeley, boulder-clay 72; Thaxted, boulder-clay 28½ on gravel and sand 48½; Wenden, clay, loam, sand and gravel 253 feet on boulder-clay 19 feet; Wimbish, boulder clay 44 on gravel and sand more than 32 feet.

In the one-inch Map 223[1]:—Bocking, boulder-clay 29 on sand and gravel 22½; Coggeshall, clay and sand 35 on clay 37; Halstead, boulder-clay 20 on sand 70; Wakes Colne, boulder-clay 31 on sand and gravel 30 feet.

In the one-inch Map 240[1]:—Harlow, clay and sand 66; Hatfield Broadoak, gravel and sand 6 or 7 on clay 120 feet; Little Hallingbury, gravel and boulder-clay 55 on sand to 5; Sheering, clay, loam, sand and gravel to 75 feet.

In the one-inch Map 241[1]:—Chelmsford, gravel and sand to 67; Witham, gravel and silt 40 on boulder-clay 29 feet.

In the one-inch Map 258[1]:—Helion Bumpstead, boulder-clay 125 on sandy loam 11½.

In this list the records at Quendon, Newport, Wenden, Littlebury and Great Chesterford call for especial notice. They range along the valley of the Cam and show the existence of a deep channel extending to below sea-level,[2] and ranging, as recently proved by a boring at Whittlesford in Cambridgeshire (p. 24) for upwards of 11 miles. In the following table the records referred to are arranged from north to south. The elevations are given in feet, and the height of the rock-surface above or below Ordnance Datum is indicated by the signs + and — respectively.

	Quendon Hall.	Newport.	Wenden.	Littlebury.	Great Chesterford.	Whittlesford (Cambridgeshire).
Elevation of surface ...	300	200	230	157	142	120
Depth to base of Drift ...	142	More than 340	272	More than 218	156	More than 455
Elevation of rock-surface ...	+158	More than —140	— 40	More than — 61	— 14	More than —335

[1] The scale of the map on p. 53 does not admit of the insertion of all the names here mentioned. They are therefore located approximately by reference to the New Series One-inch Map.

[2] W. Whitaker. *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 333.

Pliocene.

Crag.

A few outliers of Red Crag are found in the north-eastern part of Essex, resting on the London Clay. They consist of coarse current-bedded ferruginous sand. The sand is crowded in parts with broken shells, and in the lower part contains rolled phosphatic nodules (1). It is of limited distribution, and only a few feet thick.

Eocene.

Bagshot Beds.

These sands graduate down into the London Clay by alternations of sand and loam. They include gravels composed chiefly of flint-pebbles imbedded in a clayey matrix. Two of the borings in the table following p. 56 started in Bagshot Beds, and at Great Warley a thickness of 45 ft. was definitely assigned to that formation. At Brentwood there may be probably a thickness of 41 ft. (5); in other outliers somewhat less has survived denudation. At Laindon, or Langdon, Hill the Bagshot Beds were not bottomed at 39½ ft. (3 and 5).

London Clay.

This sub-division, except for the passage beds at the top, consists almost wholly of soft brown, blue, or grey clay, with occasional septaria. Its thickness has been determined as more than 532 ft. at Ingatestone, and as 493 ft. at Great Warley, where it is overlain by Bagshot Beds. At Brentwood a boring shows 483 ft., under what was thought to be Bagshot Beds. Among other notable but incomplete measurements may be mentioned 417 ft. at Southend, 410 ft. at Rayleigh, 394 ft. at Chelmsford, 385 ft. at Burnham, and 380 ft. at Shoeburyness (5). Though the London Clay attains its full development under outliers of Bagshot Beds, it is far from doing so under outliers of Crag. In the latter case the part removed by denudation before the Crag was deposited may amount to upwards of 300 ft. A large proportion of the wells in Essex have been sunk through the London Clay, and for the thickness of that formation existing at any given spot, reference should be made to the Geological Survey Memoir on the Water Supply of Essex, now in the press.

Lower London Tertiaries.

Under this general title are included:—

	South and East Essex.		North and West Essex.
	Ft.		Ft.
Oldhaven and Blackheath Beds—fine sand crowded with flint-pebbles	25	to	0
Woolwich and Reading Beds, grey shelly clay, and sands irregularly interbedded with brightly-coloured clays	20	to	60
Thanet Sand, quartzose sand with some green grains and argillaceous matter. At the base a layer of unworn flints with a green coating	10–100	to	0

The Oldhaven Beds, where characteristically developed, are separable from the London Clay above and the Woolwich Beds below. To the south-east of London they consist chiefly of perfectly rolled shingle, and at times eat deeply into the underlying strata, or even overlap them. In Essex the pebbly facies is represented, but the beds may consist almost wholly of sand. In the north and west the Oldhaven Beds are absent.

The Woolwich and Reading Beds vary rapidly in character, clay or sand predominating in neighbouring spots. They rest on a somewhat eroded surface of the Thanet Beds, and contain flint-pebbles at their base. Where they rest directly on the Chalk, a layer of angular and green-coated flints rests upon the surface of the Chalk, and that surface is eroded and piped. In northern Essex the Woolwich Beds range from 50 to 60 ft. in thickness, and in Southern Essex from 20 to 50 ft.

The Thanet Sand maintains a greater regularity in its character than the Woolwich Beds, but is not always present. It reaches its greatest thickness of more than 100 ft. towards the east, and is absent or thin through much of northern Essex.

These sub-divisions in the strata between the London Clay and the Chalk are often difficult to determine. Taken together, they show the following measurements, as deducted from the table following this page:—

In West Essex[1] their thickness ranges from a minimum of 44 ft. in the north (Felstead) to a maximum of 147½ ft. in the south (Horndon).

In Mid Essex[1] it ranges from a minimum of 44 ft. in the north (Henny) to a maximum of 181 ft. in the south (Southend).

In East Essex[1] it ranges from a minimum of 30 ft. in the north (Harwich) to a maximum of 129 ft. in the south (Foulness).

Cretaceous.

Chalk.

The Upper Chalk and a part of the Middle Chalk come to the surface in Essex, but the whole of the formation has been traversed in borings at Loughton, East Ham, Weeley and Harwich. From these it appears that the total thickness ranges from 685½ to 647 ft. in the south-west of Essex and from 822½ to 890 ft. in the north-east of the county. A further expansion takes place in Suffolk (p. 128). In the Weeley boring the three subdivisions of the Chalk were recognised with some probability; 420½ ft. were assigned to the Upper, 228½ ft. to the Middle, and 173½ to the Lower Chalk (5).

Upper Greensand and Gault.

The Upper Greensand and Gault together decrease in thickness from 200 ft. in the south-west of Essex (East Ham) to 76 ft. at Weeley and 61 ft. at Harwich in the north-east. This attenuation continues in Suffolk and Norfolk (pp. 128 and 100). At Loughton 30 ft. of green sand and calcareous sandstone, lying above the

[1] By West Essex is meant that part of the county which is included in the New Series One-inch Maps 205, 222, 239, 240, 256, 257 and 271; Mid Essex is that part which lies within Sheets 206, 223, 241 and 258; and East Essex is included in Sheets 224, 242, 259. The limits of these sheets are indicated in Fig. 11, p. 53.

To face page 56.

PRINCIPAL BORINGS IN ESSEX. (*Thicknesses in feet.*)

WEST ESSEX, FROM NORTH TO SOUTH. | MID ESSEX FROM NORTH TO SOUTH.

	Saffron Walden. (205)*	Felstead. (222)	Great Dunmow. (222)	Waltham Abbey. (239)	Hatfield Peverel, S.W. of Witham. (241)	Roydon. (240)	Nazeing. (240)	Roxwell. (240)	Ingatestone. (240)	Chingford. (256)	Walthamstow. (256)	Leyton. (256)	Lea Bridge. (256)	West Ham. (257)	Loughton. (257)	East Ham (Beckton). (257)	Ilford. (257)	Barking. (257)	Romford. (257)	Brentwood. (257)	Great Warley. (257)	Horndon. (257)	Henny. (205)	Great Saling. (222)	Braintree. (223)	Stisted. (223)	Halstead. (223)	Earls Colne. (223)	Chelmsford. (241)	Great Baddow. (241)	Maldon. (241)	Layer Marney. (241)	Tollesbury. (241)	Mundon. (241)	Pitsea. (258)	Thundersley. (258)	Rayleigh. (258)	Burnham. (258)	Leigh. (258)	Southend. (258)	Shoeburyness. (258)
Alluvium and Gravel	—	—	—	—	—	—	—	—	—	10	22½	16	18	16	—	26	18	17	—	—	—	—	—	—	—	—	—	—	—	—	—	18	—	14	—	—	26	—	—	54
Glacial	10	51	14	—	9	—	—	51	—	—	—	—	—	—	—	—	—	—	—	—	—	—	76	75	14	—	7	—	16	—	—	—	—	—	16	—	—	—	—	—
Bagshot Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(?) 41	45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
London Clay	—	209	99	225	181	14	87½	268	532	54	48½	19	10	38½	167	—	111½	39	52	483	493	106	40	165	136	205	97	167[4]	394	336[4]	206[4]	242	179	156	233	341	410	385	359	417	380
Oldhaven Beds	—	—	—	—	—	—	—	}	} 65	—	}	—	—	—	—	—	—	—	—	20½	—	} 43½	—	—	—	4	—	—	18	} 62	81	—	—	11	}	—	—	—	21	}	(?) 26
Woolwich Beds	—	} 44	} 57½	58	} 100	50	50½	} 105		41½	} 86	35	} 57	53	36	} 102	36½[3]	49	38½	49½	47		34	60	45	42	41	38	} 106½			} 84	103	} 103	} 147½	142	140	to 34½	} 140	} 181	21
Thanet Sand	—			21		—	—		49	36		40		47	40		37[3]	52	73½	73	81½	104	10	—	33	36½	25	38		48	63					—	—	—			(?) 10
Upper Chalk	54	to 100	to 129½	to 76	to 116	to 56	to 9	to 34	to 153½	to 309½	to 56	to 55	to 50	to 345½		—	to 137	to 235	to 224[2]	to 16	to 335½	—	to 80	to 110	to 17	to 52½	to 30	to 107	to 5½	to 304	to 284	to 243	to 58	to 55	} to 460½	to 351	to 1½	—	to 80	to 302	to 309
Middle Chalk	213	—	—	—	—	—	—	—	—	—	—	—	—	—	} 685½	647	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(?) 14
Lower Chalk	}	—	—	—	—	—	—	—	—	—	—	—	—	—	}	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 8
Upper Greensand and Gault ...	} 736	—	—	—	—	—	—	—	—	—	—	—	—	—	to 172[1]	200[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jurassic	}	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palæozoic Rocks	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* These numbers refer to the New Series one-inch Map.

[1] The base of the Gault is believed to have been reached.
[4] This may include some superficial deposits.

[2] Of which 37 feet were described as Upper Greensand.
[3] Of this thickness 24 feet may have belonged to the London Clay.

[3] Other records near Ilford show Woolwich Beds up t

PRINCIPAL BORINGS IN ESSEX. (*Thicknesses in feet.*)

H.

MID ESSEX FROM NORTH TO SOUTH.

EAST ESSEX FROM NORTH TO SOUTH.

Loughton. (257)	East Ham (Beckton). (251)	Ilford. (257)	Barking. (257)	Romford. (257)	Brentwood. (257)	Great Warley. (257)	Horndon. (257)	Henny. (203)	Great Saling. (222)	Braintree. (223)	Stisted. (223)	Halstead. (223)	Earls Colne. (223)	Chelmsford. (241)	Great Baddow. (241)	Maldon. (241)	Layer Marney. (241)	Tollesbury. (241)	Mundon. (241)	Pitsea. (258)	Thundersley. (258)	Rayleigh. (258)	Burnham. (258)	Leigh. (258)	Southend. (258)	Shoeburyness. (258)	Fobbing. (258)	Canvey. (258)	Colchester. (224)	Manningtree. (224)	Bralfield. (224)	Ramsey. (224)	Harwich. (224)	Weeley. (224)	Walton-on-Naze. (224)	Peldon. (242)	Clacton-on-Sea. (242)	Foulness. (259)
—	26	18	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18	—	14	—	—	26	—	—	54	71	76	21	25	—	—	25	—	—	—	20	70
—	—	—	—	—	—	—	—	76	75	14	—	7	—	16	—	—	—	—	—	—	16	—	—	—	—	—	—	—	—	—	26	—	—	—	—	—	—	—
—	—	—	—	—	(?) 41	45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
167	—	111½	39	52	483	493	106	40	165	136	205	97	167[4]	394	336[4]	206[4]	242	179	156	233	341	410	385	359	417	380	(?) 9	236	72	17	111	36½	23	125	116	200	170	303
—	—	—	—	—	20½	—	43½	—	—	—	4	—	—	18	62	81	—	—	11	—	—	—	— to	21	181	(?) 26	174	13	—	—	—	—	10	—	—	107	—	(?) 13
36	102	36½[3]	49	38½	49½	47		34	0	45	42	41	38	106½			84	103	103	147½	142	140	34½	140		21		37	55	38	59	50	20	71	57		80[5]	(?) 30
40		37[3]	52	73⅓	73	81½	104	10	—	33	36½	25	38		48	63					—	—	—			(?) 106		104	6	—	—	—	—		—	—	—	(?) 86
	—	to 137	to 235	to 224⅔	to 16	to 335½	—	to 80	to 110	to 17	to 52½	to 30	to 107	to 5½	to 304	to 284	to 243	to 58	to 55	to 460½	to 351	to 1½	—	to 80	to 302	to 309	to 22	to 26	to 43	to 40	to 267	to 110	to	420½	to 123	to 243	to 20	to 59
685½	647	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(?) 144	—	—	—	—	—	—	890	228½	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 8	—	—	—	—	—	—		173½	—	—	—	—
to 172[1]	200[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	61	76	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	to 45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 69	to 127	—	—	—	—

[1] Fault is believed to have been reached. This may include some superficial deposits.

[2] Of which 37 feet were described as Upper Greensand.

[3] Other records near Ilford show Woolwich Beds up to 55 feet and Thanet Sand up to 59 feet in thickness.

[4] Of this thickness 24 feet may have belonged to the London Clay.

Gault Clay, was assigned to the Upper Greensand, and at East Ham a thickness of 37 ft. was assigned to that formation, presumably a similar evidence (5).

Lower Greensand.

Lower Greensand is sometimes assumed to have been reached at Loughton, but as a fact no specimen was obtained that could be so described. Water was struck and boring-operations ceased about 172 ft. below the base of the Chalk (3).

Oolitic.

Rocks of Oolitic age are believed to have been reached at Saffron Walden. All however that is known is that a great mass of marl and clay was passed through which was believed to include part of the Kimmeridge and Oxford Clays (2).

GLOUCESTERSHIRE.

Table of Strata.

		Thickness in feet.
Superficial ..	Alluvium	to 20
	Glacial	to 76
Oolitic ...	Oxford Clay	not proved.
	Kellaways Rock	75
	Cornbrash	13–16
	Forest Marble	40–100
	Bradford Clay	0–8
	Great Oolite	70–160
	Fuller's Earth	1–84
	Inferior Oolite	50–250
	Midford Sands	12–145
Liassic ...	Upper Lias	100–200
	Middle Lias	60–280
	Lower Lias	961
Triassic ...	Rhaetic	20–48½
	Keuper Marl	481
	Keuper Sandstone	to 74
	Bunter	—
Palæozoic rocks		—

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SUPERFICIAL.

Glacial.

Glacial deposits occur only in the north-eastern parts of the county. The greatest thickness was found on the hill above Mickleton Tunnel, where 76 ft. of sandy drift lies upon the Lias (1).

OOLITIC.

Oxford Clay with Kellaways Beds.

The full thickness has not been ascertained in Gloucestershire, but a boring at South Cerney showed 106 ft. of Oxford Clay and Kellaways Beds, of which about 75 ft. were assignable to the Kellaways Beds (3).

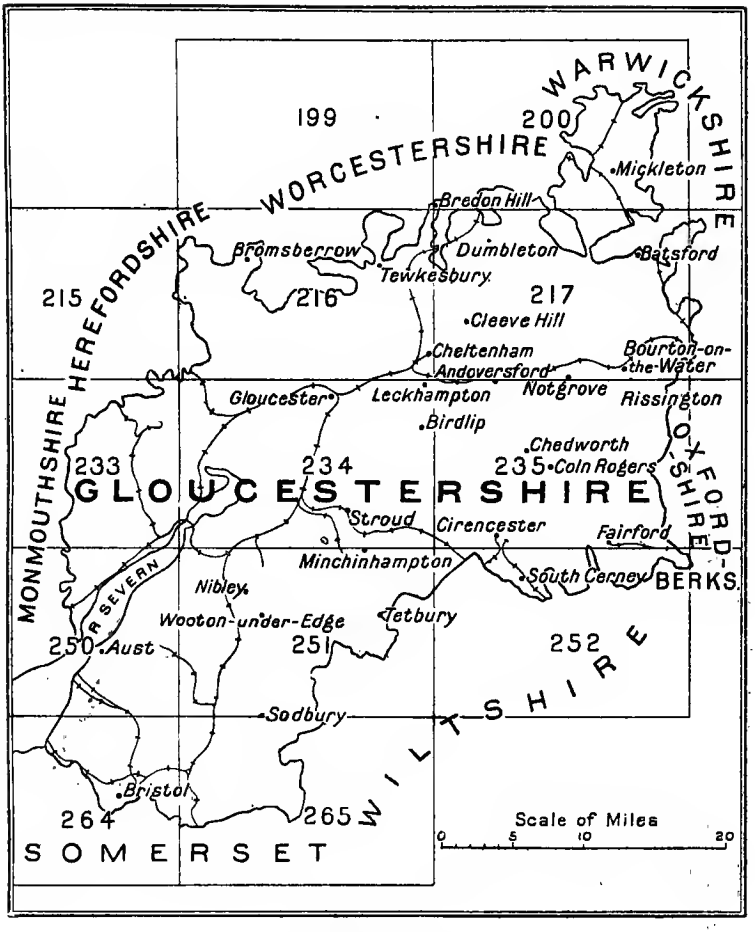
Cornbrash.

The Cornbrash consists of about 13 to 16 ft. of rubbly limestone (2).

Forest Marble.

The Forest Marble consists of shelly marl, green and grey clay and rubbly limestones with some sandstone. It is more than 100 ft. at Cirencester (2), but at Tetbury 60 ft. (2), and at Coln Rogers only 40 ft. thick (2). The basal bed, known as the Bradford Clay, is never more than 8 ft. thick and in many places cannot be distinguished as a distinct bed (2).

FIG. 12. GLOUCESTERSHIRE.



Great Oolite.

This consists of oolitic and rubbly limestones with beds of calcareous clay and sands. In the neighbourhood of Cirencester and Minchinhampton it is from 70 to 90 ft. thick, but at Chedworth it is 120 ft. and at Tetbury 160 ft. thick.

The basal bed, known as the Stonesfield Slate, is not well developed in Gloucestershire.

Fuller's Earth.

This bed of clay is 84 ft. thick at Tetbury (2), but seems to thin northward, as it is 50 ft. thick at Chedworth (2), 25 to 30 ft. near Notgrove (2), and only 1 ft. thick at Rissington.

It is not of any economical value as fuller's earth.

Inferior Oolite.

This series has a varied development in Gloucestershire. The maximum thickness of 250 ft. is reached at Cheltenham (2).

The local divisions and variations in thickness are given in feet in the following Table (2):—

MEASURED SECTIONS OF THE INFERIOR OOLITE.
(*Jurassic Rocks of Britain, Mem. Geol. Surv.*, vol. iv.)

		Sodbury.	Nibley.	Stroud.	Leckhampton.	Andoversford and Chedworth.	Andoversford and Bourton-on-the-Water.	Cleeve Hill.	North end of Cotteswold Hills.
Ragstones	Clypeus Grit...	20 to 30	$6\frac{1}{2}+$	24 to 34	—	15	35 to 40	34	5
	Upper Trigonia Grit ...				$8\frac{1}{2}$	25	2 to 5		$1\frac{1}{2}$
	Notgrove Oolite				—	—	10		18
	Gryphite Grit				6	18	15		8
	Lower Trigonia Grit ...				7	—	—		—
Freestones	Upper Freestone	25 to 30	38	74 to 116	20 to 25	18	8 to 14	47	20
	Oolite Marl				7 to 10	—	30	10	16
	Lower Freestone				130	38	25	60	90
	Pea Grit Series	—	—	27 to 38	38	24	—	35	—
Midford Sands	Cephalopoda Beds	5 to 15	$15\frac{1}{2}$	115	1 to 4	28	12 to 15	25	25
	Cotteswold Sands	30 to 40	130		20				

Midford Sands.

The Midford Sands form a passage into the Upper Lias. They reach their greatest thickness of 145 ft. in the south.

Liassic.

The total thickness of the Lias in North Gloucestershire is given as 1,360 ft. (1). In the south of the county it is much thinner.

The Upper Lias varies from 100 ft. on Bredon Hill to 150 ft. at Dumbleton and 200 ft. at Leckhampton (1).

The Middle Lias varies from 60 ft. to 280 ft. At Wooton-under-Edge it is estimated as being 200 ft. thick.

The upper 2 to 15 ft. of the Middle Lias is a hard ferruginous sandy limestone, known as the 'Marlstone'; the lower beds are sandy clays with ferruginous bands and nodules (1).

The boring at Mickleton (p. 62) proved the Lower Lias to be 961 ft. thick (1).

Triassic.

The Rhaetic beds are well exposed in the banks of the Severn where the river runs along the junction of the Jurassic and Triassic rocks.

The upper division is known as the White Lias, which is about 20 ft. thick; below this lie about 30 ft. of black shales with some grey sandy beds and the well-known bone-bed at the base (4). In the north of the county, at Mickleton and Batsford, the Rhaetic group, as thus defined, had a thickness of 44 and 48½ ft. respectively (1, 5).

Below the Rhaetic shales lie the Tea-green Marls which pass downwards into the normal red marls of the Keuper.

In the Batsford boring there were 481 ft. of marls above 74 ft. of Keuper Sandstone (5). In the south of the county the basal bed of the marls is often a dolomitic conglomerate which lies in hollows in the pre-Triassic floor.

A small area around Bromsberrow is occupied by Upper Bunter Sandstone (4), but elsewhere in the county this formation appears to be absent and the Keuper rests directly on the Carboniferous or older rocks.

Principal Borings in

GLOUCESTERSHIRE.

Thicknesses in feet.

	Mickleton.	Batsford.	Birdlip.	Cirencester.		Fairford.	Tetbury.	South Cerney.
Alluvium and Glacial	—	—	—	25	19	11	—	18
Oxfordian	—	—	—	—	26	—	—	106
Cornbrash	—	—	—	—	13½	—	—	to
Forest Marble ...	—	—	—	108 to 6	66 to 53	3	8	—
Great Oolite ...	—	—	—			55½	160	—
Fullers Earth ...	—	—	—	—	—	44½	84 to 48	—
Inferior Oolite ...	—	—	187	—	—	to		—
Midford Sands ...	—	—	116½	—	—	—	—	—
Upper Lias	—	—	to	—	—	—	—	—
Middle Lias	280	—	—	—	—	—	—	—
Lower Lias	961	418	—	—	—	—	—	—
Rhaetic	44 to 57	48½	—	—	—	—	—	—
Keuper Marl ...		481	—	—	—	—	—	—
Keuper Sandstone ...	—	74 to 679	—	—	—	—	—	—
Palæozoic	—		—	—	—	—	—	—

HAMPSHIRE, INCLUDING THE ISLE OF WIGHT.

Table of Strata.

		Thickness in feet.
Superficial	Peat, Alluvium	—
	Valley Gravel	—
	Plateau Gravel, Clay and Gravel with flints	—
Oligocene ...	Hamstead Beds	up to 256
	Bembridge Beds	70–120
	Osborne Beds	80–119
	Headon Beds	147–212
Eocene ...	Upper Bagshot or Barton Sand and Headon Hill Sand	80–244
	Barton Clay and Bracklesham Beds ...	up to 580
	Lower Bagshot Beds	15–662½ ft.
	London Clay	118–336
	Reading Beds	60–163
Cretaceous ..	Upper, Middle and Lower Chalk ...	up to 1,645
	Upper Greensand and Gault (Selbornian)	270–330
	Lower Greensand	400–800
	Wealden Beds ...	supposed more than 2,000

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SUPERFICIAL.

Peat-bogs are common in the New Forest over areas of water-logged sand (7). Clay-with-flints, or unstratified angular gravel-with-flints, is spread widely on the Chalk slopes of central Hampshire. Plateau-gravel covers considerable areas in southern Hampshire and the Isle of Wight; the gravel of St. George's Down is dug to a depth of more than 30 ft., but the full thickness may be considerably more. North of St. George's Down there are shallow pits in plateau-gravel showing 5 or 10 ft. of gravel resting on Oligocene Clay (6).

OLIGOCENE.

The Hamstead Beds are marine, freshwater and estuarine marls. They attain a thickness of about 256 ft. in Hamstead Cliff, and exceed 200 ft. at Parkhurst Forest and at Wootton (6).

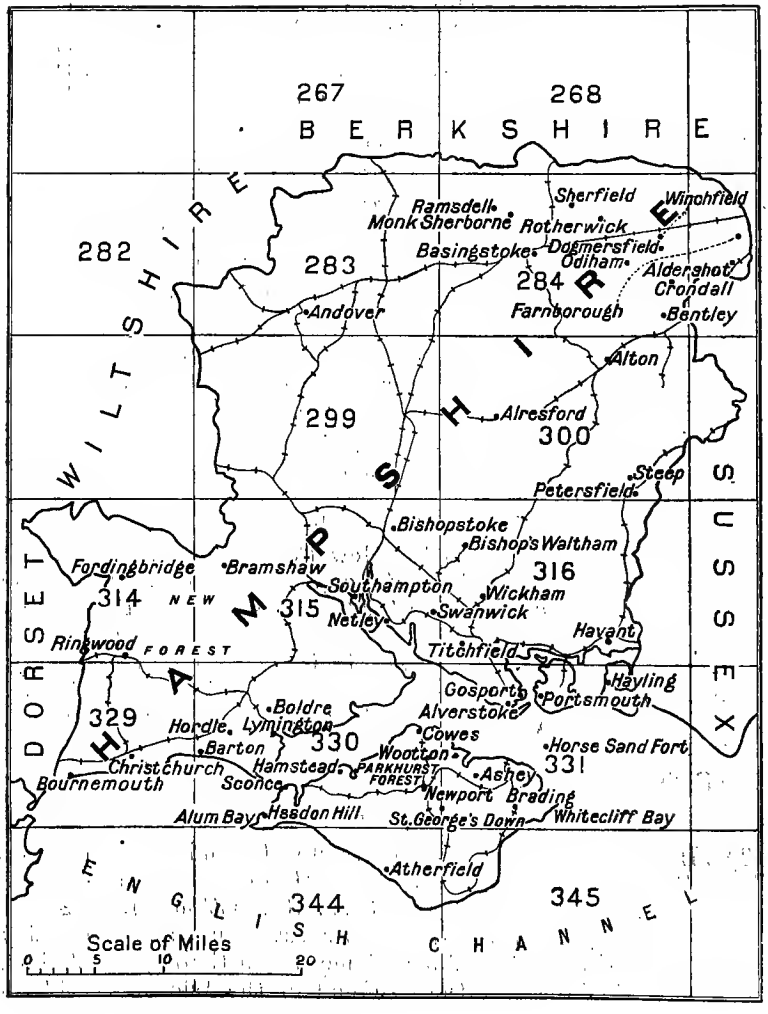
The Bembridge Beds are freshwater, estuarine and marine clays and marls resting on limestone. They reach their greatest thickness of about 120 ft. at the east end of the Isle of Wight but

dwindle to 70 ft. towards the west. The Bembridge Limestone is about 15 to 16 ft. thick at Headon Hill; at Sconce from 16 to 20 ft. and in Whitecliff Bay 24 to 27 ft., but it appears to be thin near Newport (6).

The Osborne Beds are composed of clays, shales, marls and concretionary limestones. Their thickness varies from about 80 ft. at the east and the west ends of the Isle of Wight to 103 to 119 ft. at Cowes and Newport (6) and 117 at Wootton (9).

The Headon Beds are composed of freshwater, estuarine and marine sands, clays and limestone-bands of a variable nature. Their total thickness is estimated to be 147 ft. at Headon Hill and 212 ft. at Whitecliff Bay (6). At Boldre they were bored through for 168 ft. (top absent) and at Bembridge for 114 ft. (base not reached). At Newport their full thickness was proved to be 204 ft. (9).

FIG. 13. HAMPSHIRE, INCLUDING THE ISLE OF WIGHT.



Eocene.

Barton and Bracklesham Beds.

In the Isle of Wight, between the Headon Beds and the Barton Clay lie some yellow and white sands known as the Barton (or Headon Hill) Sands, which probably belong to a higher zone than the Upper Bagshot series of the London Basin. At Headon Hill they are about 110 ft. thick; in Alum Bay they are probably from 140 ft. to 200 ft. At Bembridge they were proved to be 244 ft. thick (9). In Whitecliff Bay they are 184 ft. (6). On the mainland the Barton Sands are usually from 80 to 100 ft. thick (7). Barton Clay in that district is well shown at Barton and Hordwell. It consists of sandy clays and sands, with layers of septaria, and its thickness in South Hampshire may amount, in places, to nearly 350 ft. At Dibden it was proved to be 349 ft., at Lymington 227 ft., and at Milton 125 ft. thick (9). But the gradual passage of the Bracklesham Beds beneath into the Barton Clay above makes the exact limit difficult to determine. In the Isle of Wight a measured section in Alum Bay showed a thickness of 255 ft. of Barton Clay; another in Whitecliff Bay 162 ft. 1 in. (6).

The Bracklesham Beds are mainly of marine origin. In Alum Bay the lower beds are clays and marls, the middle beds sands, and the upper beds dark sandy clays. The lower beds contain lignite. They are best shown in Whitecliff Bay, where their total thickness is about 580 ft. (6), though in Alum Bay it is only about 155 ft.

A borehole made for the supply of Horse Sand Fort, in the channel between the Isle of Wight and the mainland, entered Bracklesham Beds under the recent deposits and did not reach their base at 569 ft., proving them to be more than 471¼ ft. thick.

On the mainland they have been proved to exceed at Southampton, 232 ft.; at Netley, 260 ft.; at Gosport, 294 ft.; at Bishop's Waltham, 96 ft.; in all these cases the top being absent. In several wells the thicknesses of Bracklesham and Lower Bagshot Beds are more suitably quoted in combination, in consideration of the difficulty of separating the two formations. Thus, at Christchurch, the thickness of Bracklesham (top absent) and Bagshot Beds exceeds 370 ft. at Bournemouth; nearly 300 ft. of sand, all attributed to the Lower Bagshot, have been proved. At Aldershot a part of the Bracklesham Beds with the Lower Bagshot amounted to 168 ft.

Lower Bagshot Beds.

In northern Hampshire the thickness has been estimated at 50 to upwards of 100 ft., though there are places where there seems to be room for not more than 30 to 40 ft. between the Bracklesham Beds and the London Clay (10). Clays are developed in the lower part and a bed of the exceptional thickness of 28 ft. was sunk through at Ramsdell (1). The boring at Wellington College, just outside the Hampshire boundary and quoted on p. 15, showed 158 ft. of Lower Bagshot Sand and 34 ft. of passage-beds into London Clay.

In southern Hampshire, on the mainland, the Bagshot Beds consist mainly of sands, loam and flint-pebbles. In the east their thickness is perhaps not more than 15 ft., while westward, north

of the New Forest, it is 200 ft. or more (7). At Southampton and Portsmouth the thickness ranges from 30 to 45 ft., and at Titchfield it is about 25 ft. (9). To the west of the Test it is estimated at not less than 100 ft. and near Bramshaw is believed to reach 200 ft. (7).

In the Isle of Wight the Lower Bagshot Beds attain a thickness of 662½ ft. towards the west, in Alum Bay, and include beds of pipe-clay and some lignite. At the eastern end of the island the pipe-clay has disappeared, and the thickness is reduced to about 100 ft. or possibly the upper portion has become inseparable from the Bracklesham Beds (6).

London Clay.

This formation consists chiefly of blue clay with septarian nodules, but becomes sandy in its upper part, so as to graduate into the Bagshot Beds. In northern Hampshire it has been proved to be about 241 ft. thick near Rotherwick (9), 335½ ft. at Dogmersfield (Pilcot) (10) and to exceed 332 ft. at Aldershot (9), but it dwindles rapidly westwards and is probably not more than 60 or 70 ft. thick on the north-western margin of the county (11).

In southern Hampshire, on the mainland, the following measurements (9) are arranged from east to west:—Portsmouth, 300 to 332 ft.; Gosport, 327 to 336 ft.; Southampton, 301 ft.; Christchurch, 325 ft.; Fordingbridge, 118½ ft.

In the Isle of Wight the thickness has not been determined in borings but is estimated at 320 ft. in Whitecliff Bay, and at 233 ft. in Alum Bay, at the eastern and western ends of the island respectively.

Reading Beds.

In northern Hampshire the Reading Beds include a considerable thickness of mottled clay in the upper part, and sands with clays in the lower part. At Aldershot the thickness assigned to them varies greatly, but may be taken to average 68 ft. Near Crondall, Odiham and Monk Sherborne it varied from 60 to 75 ft. At Rotherwick, farther within the Tertiary area, it was about 80 ft., and at Sherfield, 68½ ft. (9).

In southern Hampshire, on the mainland, these beds have been bored through in many places (9). The following localities are arranged from east to west:—Havant, 109 ft. or more; Hayling, 120 ft.; Gosport and Alverstoke, 130 to 97 ft.; Wickham, 102 ft.; Swanwick, 113 ft.; Bishopstoke, 99 ft.; Southampton, 85 ft.; Fordingbridge, 73½ ft.; Christchurch, 98 ft. In some of the borings the whole or nearly the whole of the Reading Beds consisted of clay.

In the Isle of Wight also the Reading Beds consist almost entirely of clays, usually mottled. The thicknesses, as estimated, diminish from east to west as shown in the following localities:—Whitecliff Bay, 163 ft.; Brading, 140 ft.; Ashey, 92 ft.; Downend, 110 ft.; Alum Bay, 84 ft. (6).

CRETACEOUS.

Chalk.

The Chalk of Hampshire has not been completely traversed in any one boring, and though it has been tapped by borings in parts

of the Hampshire Tertiary Basin, its base has not there been reached. The base, however, comes to the surface near the north-western, eastern and southern margins of the county.

The following estimates of thickness have been made:—

	North of the Hampshire Tertiary Basin.					Isle of Wight.	
	Basingstoke District.	Alresford District.	Andover District.	Salisbury District.	Southampton.	East End.	West End.
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Upper Chalk	380	550	400–500	790	1,200–1,250	1,240–1,350	—
Middle Chalk	200	200	120–150	80–100		194	150
Lower Chalk	170	180–190	220	190		206	161

[1] That is the parts of Hampshire which lie nearest to Salisbury in Wiltshire.

The irregularity in thickness of the Upper Chalk is partly accounted for by the unconformity at the base of the Tertiary deposits, and it has been generally assumed that its thickness over much of central Hampshire amounts to 680 or 700 ft.

In the Middle and Lower Chalk a westward attenuation is to be noted.

Upper Greensand and Gault (Selbornian).

In the north-eastern part of Hampshire the Selbornian group includes a few feet of green sand (which is developed near and south of Alton), a group of marls and malmstone more or less siliceous, and a lower division of clay with some sand at the base. The malmstone-division passes down into the clay, and is by its fossils allied to Upper Gault.

In the north-western part of the county a few feet of greenish sand come in above the malmstone, and develop both westwards into Wiltshire and southwards into the Isle of Wight.

In the Isle of Wight a division of the Selbornian into an upper member consisting of sand with much chert in the upper part (Upper Greensand) and a lower member consisting chiefly of clay (Gault) is more readily made, though here also the one passes down into the other.

The following table gives the relative thicknesses of the lithological divisions referred to:—

	N. E. Hampshire (10).	N. W. Hampshire (9).	Isle of Wight (6).
Greensand	0 to a few feet.	More than 130	121 to 80
Marls, malmstone and passage-beds ...	100		94½ to 73
Clay	170	Unknown.	146 to 120.
Sand	15	—	—

A well at Bentley is reported to have traversed more than 373 ft. of Gault under 60 ft. of what was believed to be for the most part Upper Greensand (9). These exceptional thicknesses may be due to local disturbance and require confirmation. At Alton the "Malm Rock" was proved in a well to be 80 ft. thick and the Gault 192 ft., the latter possibly including some Lower Greensand. These measurements agree approximately with the estimates given in the Table on p. 67. On the other hand at Steep a well starting in Gault reached its base at 241½ ft. depth, showing the total thickness here to be probably over 250 ft., without including any Upper Greensand, which may here be 80 ft. in thickness.

Lower Greensand.

This formation crops out on the eastern margin of Hampshire and in the Isle of Wight, but has not been proved in other parts of the county.

In eastern Hampshire its thickness has been estimated at 425 ft., made up as follows (2, Plate IV.):—

Near Petersfield.

	Feet.
Folkestone Beds, almost wholly sands	100
Sandgate Beds, sands and clays	75
Hythe Beds, calcareous stone, chert, and sand with some clay	200
Atherfield Clay	50

At Petersfield several wells have been sunk in the Lower Greensand, but none afford complete measurements. The deepest, starting and ending in this formation, was sunk to 279 ft. depth.

In the Isle of Wight the following measurements have been made:—

	Isle of Wight.	
	East End. Ft.	West End. Ft.
Carstone, brown sand with pebbles	72¾	6
Sandrock Series, white and yellow sand with some clay-beds	93½	81½
Ferruginous Sands, white and dark sand with a little clay	367½	251½
Atherfield Clay	83¾	60
	617	399

At Atherfield, on the south side of the island, the thickness is estimated at over 800 ft. It appears, therefore, that the Lower Greensand is thinning in a direction a little west of north towards central Hampshire.

Wealden.

On the mainland in Hampshire nothing is known of these beds. In the Isle of Wight there are exposed to view nearly 1,000 ft. of Wealden Beds, consisting in the upper part of shales, but in the main of red and variegated clays with irregular sandstones. The total thickness of the formation can only be guessed at, but is likely to exceed 2,000 ft.

PRINCIPAL BORINGS. (*Thicknesses in feet.*)

	NORTHERN HAMPSHIRE.						CENTRAL HAMPSHIRE.			SOUTHERN HAMPSHIRE.													ISLE OF WIGHT.					
	Rotherwick.	Pilcot, near Winchfield.	Crondall.	Aldershot, South Camp.	Aldershot, Messrs. Simmonds.	Farnborough.	Alton.	Steep.	Petersfield.	Fordingbridge.	Ringwood.	Bournemouth.	Milton.	Lymington.	Dibden, near Southampton.	Southampton.	Netley.	Titchfield.	Alverstoke.	Gosport.	Portsmouth.	Havant.	Hayling.	Freshwater.	West Cowes.	Newport.	St. Helens.	Bembridge.	Spithead, Horse Sand Fort
Superficial	—	—	—	—	12	7	—	5	—	14	9½	13	—	15	24	4½	—	8	—	12	7	17	57	—	10	12	—	—	70¼
Hamstead Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29	} 157	15	—	—
Bembridge Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	116		118½	51	—
Bembridge Limestone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9	6	16 to	1	—
Osborne Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74	103½ to	119	25½	} to	—
Headon Beds	—	—	—	—	—	—	—	—	—	—	—	—	121½	—	—	—	—	—	—	—	—	—	—	99½	169½	204	—	} 250	—
Headon Limestone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upper Bagshot or Barton Sand ..	—	—	—	—	—	128½	—	—	—	—	—	—	105	105	72	—	—	—	—	—	—	—	—	—	—	to 14	—	—	—
Barton Clay	—	—	—	—	—	—	—	—	—	—	—	—	125 to	227 to	349 to	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bracklesham Beds	—	—	—	53	—	31[1]	—	—	—	—	48½ to	— to	43	12[4]	55	41	more than 260	163½	—	291	} 99	—	—	—	—	—	—	—	to 471¼
Lower Bagshot Sand	15	40	—	115[1] to	—	62 to	—	—	—	6	348	313	—	—	—	32½	to 11	25½ to	—	25		—	—	—	—	—	—	—	—
London Clay	241	335½ to	247½	332	327	31	—	—	—	118½	—	—	—	—	—	301	—	166	64	327	300	118	221	—	—	—	—	—	—
Woolwich and Reading Beds ...	80 to	411½	68½ to	—	84 to	—	—	—	—	73½ to	—	—	—	—	—	85	—	—	97 to	130 to	126 to	122[5] to	120 to	—	—	—	—	—	—
Upper Chalk	594	—	216	—	257	—	—	—	—	7	—	—	—	—	—	} to 853	—	—	59¾	9	70	109	302	—	—	—	—	—	—
Middle Chalk	—	—	—	—	—	—	} 268	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Lower Chalk	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upper Greensand	—	—	—	—	—	—	80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gault	—	—	—	—	—	—	192[2]	236½[3] to	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Folkestone Beds	—	—	—	—	—	—	—	8½	69 to	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sandgate Beds	—	—	—	—	—	—	—	—	27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hythe Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				

[1] The uppermost 35 feet may be Bracklesham Beds.
[2] Possibly including some Lower Greensand.
[3] Total thickness estimated at over 250 feet.
[4] Identification as Bracklesham Beds doubtful.
[5] Base of Reading Beds not fixed precisely.

To face page 68.

KENT.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Blown sand, shingle, alluvium, valley gravel, brickearth, clay with flints ...	—
	Plateau gravel	—
Pliocene ...	Lenham Beds	—
Eocene ...	Lower Bagshot Sand	—
	London Clay	proved to 300
	Oldhaven and Blackheath Beds ...	20–60
	Woolwich and Reading Beds	up to 61
	Thanet Sand	50–129

			West Kent.	*East Kent.*
Cretaceous	Chalk		650	about 900
	Selbornian.	Upper Greensand	244–63	
		Gault		
	Lower Greensand.	Folkestone Beds	From 30–40 in the north to about 210 in the south.	
		Sandgate Beds		
		Hythe Beds		
		Atherfield Clay	20–43	
	Weald Clay...		More than 720 in West Kent to 15 in East Kent.	
	Hastings Beds.	Upper Tunbridge Wells Sand...	150–180	
		Grinstead Clay		
		Lower Tunbridge Wells Sand ...		
		Wadhurst Clay	160–235	
		Ashdown Sand	300 or more	
			681 proved at East Grinstead.	

Proved in borings only :—

Jurassic and Triassic.	Purbeck Beds	to 562
	Portland Beds	14–131
	Kimmeridge Clay	up to 622
	Corallian Beds	up to 342
	Oxford Clay	up to 243
	Great Oolite Series	up to 189
	Lias	up to 173
	Trias	0–81
Palæozoic Rocks		—

The Jurassic and Triassic formations gain rapidly in development towards the south-west.

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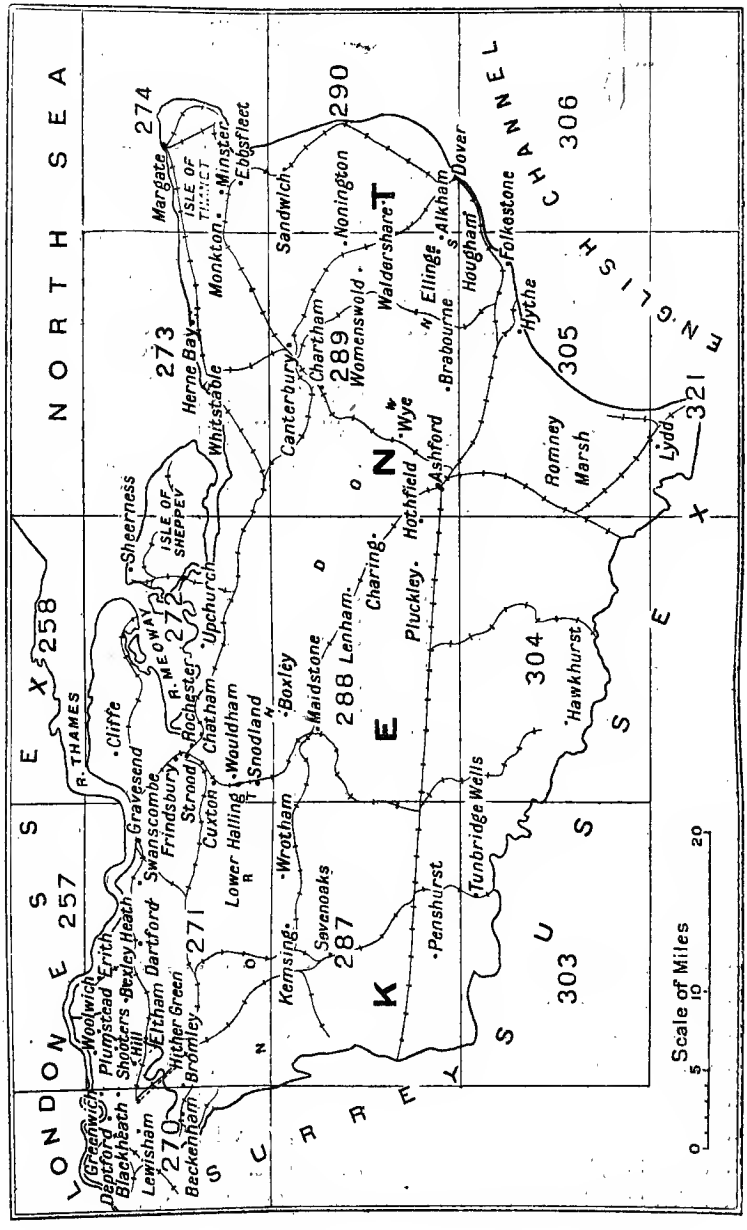

FIG. 14. KENT.

Superficial.

There are broad spreads of alluvium on the borders of the Thames and Medway, also between the Isle of Sheppey and the mainland; between Canterbury and Thanet, and at Romney Marsh.

Beneath the alluvium of the Thames a deep channel filled with gravel has been proved at the following localities. At Deptford, on the west, the total thickness of alluvium and gravel is 36 ft., increasing eastwards to about 40 to 50 ft. at Greenwich, Woolwich and Plumstead; 50 to 60 ft. at Erith and Dartford, to 77 ft. at Cliffe and 87 ft. at Sheerness. A similar deep channel occurs beneath the Medway alluvium. The deposits which fill it measure in thickness 27½ ft. at Snodland, 42 to 50 ft. in the neighbourhood of Cuxton, Chatham and Rochester, increasing to over 90 ft. near Upchurch.

The deposits beneath Romney Marsh are of about the same thickness, a well at Lydd proving some 60 ft. of alluvium. The marsh between Canterbury and Thanet is underlain by 40 ft. of sand and clay at Sandwich (7) and about 60 ft. at Ebbsfleet (10).

Thick beds of gravel and sand rest on terraces about 80 ft. above the Thames between Dartford and Gravesend and attain a thickness of over 40 ft. There are also patches of gravel on some of the hills, as at Shooter's Hill.

The Clay-with-flints overlies wide areas on the Chalk Downs. It consists of red or light-brown stiff clay enclosing unrolled flints and varies in thickness from a few inches to 20 ft., but is inconstant. Occasionally a loam or brickearth laterally replaces the clay-with-flints.

Pliocene.

A small outlier of fossiliferous Lower Pliocene sands occurs on the edge of the North Downs, at Lenham, and ironstones, probably of the same age, here and there rest on the highest part of the Down as far as Folkestone (12).

These sands usually fill cylindrical hollows in the Chalk, sometimes to a depth of 8 ft.

Eocene.

Bagshot Sand.

Only the lower part of the Bagshot Sand remains in Kent. In the Isle of Sheppey some 20 ft. of sand with thin laminæ of clay overlie the London Clay (1). At Shooter's Hill about 30 ft. of even-bedded sands and loam with ironstone concretions are found above the London Clay. These resemble similar beds at Claygate in Surrey which immediately underlie the Bagshot Beds.

London Clay.

The full thickness of London Clay has been proved only in the Isle of Sheppey, where a well at Minster traversed 300 ft. of it; this is not quite the original thickness, but cannot be far short of it as the Bagshot Beds lie only a short distance away. At Sheerness three wells pierced from 263 to 291 ft. of the clay. The area of North Kent between Sheppey and London is mostly covered with the Lower London Tertiaries, but outliers of London Clay occur here and there, as at Swanscombe and in the neighbourhood

of Woolwich and Bromley; these, however, are not more than 20 ft. thick. East of Sheppey denudation has greatly reduced the thickness; at Whitstable 65 ft., and in Canterbury 40 to 63 ft., of London Clay remain (7).

Oldhaven and Blackheath Beds.

These consist in West Kent mainly of beds of flint-pebbles in quartz-sand, while in East Kent sand preponderates. Their average thickness is some 20 ft., but they reach 60 ft. locally, as at Bexley Heath and in the neighbourhood of Blackheath.

Woolwich and Reading Beds.

These beds vary in character, but are fairly uniform in thickness. The lower beds are glauconitic sands with seams and layers of pebbles, underlying mottled brick-red, green and ochreous plastic clay, these being succeeded by greyish clay and sand. The Woolwich Beds suffered some erosion before the deposition of the Oldhaven Beds, especially in Eastern Kent.

The following list of wells which are arranged from west to east indicate the thickness assigned to these beds in Kent (7):—Deptford, 54 ft.; Greenwich, 49 ft.; Hither Green, 61 ft.; Frindsbury, 60 ft.; Sheerness, up to 53 ft.

Thanet Sand.

This sand increases in thickness from west to east as shown by subjoined measurements from well-sections (7):—Beckenham and Deptford, 52 ft.; Eltham, 49 ft.; Erith, 51 ft.; Frindsbury, near Rochester, 122 ft.; Sheerness, 93 to 117 ft.; Monkton Thanet, 129 ft.

CRETACEOUS.

Chalk.

In Kent the total thickness of the Chalk is shown in the Table of borings following p. 74, as 696 ft. at Erith, 656 ft. at Cliffe, 682 ft. at Chatham, 734 ft. at Chartham near Canterbury, and is known to exceed 834 and 820 ft. respectively at Womenswold (Ropersole) and Coldred, at both of which places the borings commenced in Chalk.

The thicknesses, in feet, of the several zones into which the Chalk has been separated have been estimated as follows:—

		Inland (3). Approximate thickness.	The Coast.[1]
Upper Chalk ...	Zone of *Marsupites*	less than 100	116 as exposed.
	„ *Micraster coranguinum* ...	300	280
	„ „ *cortestudinarium*...		56
	Chalk Rock	8	34½
	Zone of *Holaster planus*	50	
Middle Chalk ...	„ *Terebratulina gracilis* ...	50–100	161
	„ *Rhynchonella cuvieri* and Melbourn Rock	50–60	70
Lower Chalk ...	„ *Belemnitella plena*	4	193
	„ *Holaster subglobosus* with Totternhoe Stone ...	80	
	„ *Ammonites varians* ...	60–120	
			910

[1] *Proc. Geol. Assoc.*, vol. xvi, 1900, p. 320 and (5).

The coast-sections give a total thickness of 910 ft., 90 ft. more than the thickness pierced in the Coldred (Waldershare) boring, which did not commence in the highest zone of the Chalk of East Kent.

Inland there is no certain knowledge of the thickness of the Upper Chalk; but at Cliffe it was proved to exceed 423 ft.

On the coast the Middle Chalk measures 230 ft., the zone of Rhynchonella cuvieri being 70 ft. and the zone of Terebratulina 160 ft. thick (5). Inland the united thicknesses of these zones are estimated to be no more than from 100 to 160 ft. (3). The base of the Middle Chalk is well defined in Kent by the hard and nodular Melbourn Rock (5).

The Lower Chalk maintains a uniform thickness from west to east. At Chatham Dockyard it was supposed to be 191 ft. (5), while on the coast it is 193 ft. thick.

From the records cited above it is seen that the Chalk increases in thickness from west to east, an increase which is attributable to less having been removed by pre-Tertiary erosion in an easterly direction.

Upper Greensand and Gault (Selbornian).

The Selbornian of Kent consists mainly of stiff clay, but thin beds of sand overlie the clay in some localities in the west of the county. This sand is usually referred to as the Upper Greensand. It is nowhere more than 12 ft. in thickness and its identification from cores is difficult.

The Gault or clay-member of the Selbornian (4 and 7) is generally thicker on the west than nearer the coast. It has been proved in many borings, mostly near the Thames and in East Kent, but not so frequently in the intervening area. There are, however, two borings in the valley of the Medway which indicate about 230 ft. of Gault, one at Lower Halling, where there was 225 ft., and the other at Wouldham with 234½ ft. At Sundridge, near Sevenoaks, there was over 244 ft. of Gault, the maximum thickness proved in Kent. Both north and east it decreases. Some four miles north of Wouldham the thickness ranges from 190 ft. to 208 ft. as seen in the borings at Stroud, Chatham, Frindsbury and Cliffe; a northerly decrease of 20 to 30 ft. Towards the coast there is a decided but variable diminution. The following borings, including those made in search of coal in East Kent, show a general thinning of the Gault towards the east. At Charing and Wye (for water), about 190 ft.; Elham, 127 ft.; Alkham, 164 ft.; Hougham, 137 ft.; Dover Prison Well, 143 ft. Further north the Gault was 119 ft. at Womenswold, 156 ft. at Coldred, and 148 ft. at Nonington. Beneath the Isle of Thanet, however, there is a remarkable diminution, the well at Margate Waterworks proving only 63½ ft. and Ebbsfleet boring 110 ft. (10).

Lower Greensand.

		Approximate thickness in feet.
Lower Greensand.	Folkestone Beds. Coarse sands ...	110
	Sandgate Beds. Mostly clay and silt	10–80
	Hythe Beds. Soft sandstone, sometimes calcareous; some beds of chert	60–180
	Atherfield Clay. Stiff clay	20–43

In borings these divisions can seldom be recognised.

The Lower Greensand increases in thickness from north-east to south-west, as shown by the borings quoted in the accompanying table. At Alkham or Swingfield the Ellinge boring passed through 58¾ ft. of Lower Greensand, of which 19 ft. 8 in. were attributed to the Atherfield Clay (7).

Two wells in Folkestone penetrated about 230 ft., including Atherfield Clay.

Another series of wells farther west proves the persistence of the south-westward thickening of the Lower Greensand. A well at Chatham pierced 41 ft., one at Boxley, near Maidstone, 215 ft., while at Kemsing 209 ft. were found. The variation in thickness is confined to the upper beds, and of these, chiefly to the Hythe Beds. From Hythe to Maidstone the thickness of the Hythe Beds is only 70 or 80 ft., but it increases rapidly westwards and reaches 160 ft. at Sevenoaks. This thickening is due to an incoming of an upper set of sands with layers of chert (7). The Atherfield Clay, on the other hand, maintains an average thickness of 20 ft., but was 43 ft. in the Dover boring (9).

Wealden.

The Weald Clay increases in thickness in a south-westerly direction from 15 ft. at Ebbsfleet boring (10) to more than 721 ft. at Foley House near Maidstone (7). No Weald Clay was found at the Erith and Chatham borings. Following a line parallel with and south of this line we find that the clay rapidly attenuates eastwards. At Wrotham it is 669 ft. thick; at Hothfield, near Ashford, 400 ft.; at Brabourne, 109 ft., and at Dover, only 50 ft. (7 and 9).

The Hastings Beds show a similar attenuation towards the east, and a thickening in a south-westerly direction. The following three lines of boreholes indicate this:—

(1) At Erith, Chatham and Ebbsfleet they were absent.
(2) At Wrotham, 189 ft.; Foley House, 145 ft. (incomplete); at Pluckley, 310 ft.; Ashford, more than 278 ft.; Brabourne, 200 ft.; Dover, 35 ft.
(3) Penshurst, more than 552 ft.; near Tunbridge Wells, more than 393 ft.; Hawkhurst, more than 304 ft.; Lydd, more than 345 ft. (7 and 9).

Jurassic and Triassic.

Our knowledge of these formations is based, as far as regards Kent, solely on deep borings. The most reliable measurements are quoted in the following Table. The Jurassic rocks gain in thickness rapidly towards the south-west. Trias has been met with in one boring only. Presumably it would be found to attain a greater thickness in a southerly direction.

PRINCIPAL BORINGS. *(Thicknesses in feet.)*

	NORTHERN HAMPSHIRE.						CENTRAL HAMPSHIRE.			SOUTHERN HAMPSHIRE.													ISLE OF WIGHT.					
	Rotherwick.	Pilcot, near Winchfield.	Crondall.	Aldershot, South Camp.	Aldershot, Messrs. Simmonds.	Farnborough.	Alton.	Steep.	Petersfield.	Fordingbridge.	Ringwood.	Bournemouth.	Milton.	Lymington.	Dibden, near Southampton.	Southampton.	Netley.	Titchfield.	Alverstoke.	Gosport.	Portsmouth.	Havant.	Hayling.	Freshwater.	West Cowes.	Newport.	St. Helens.	Bembridge.	Spithead, Horse Sand Fort
Superficial	—	—	—	—	12	7	—	5	—	14	9½	13	—	15	24	4½	—	8	—	12	7	17	57	—	10	12	—	—	70¼
Hamstead Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29	157	15	—	—
Bembridge Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	116		118½	51	—
Bembridge Limestone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9	6	16 to	1	—
Osborne Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	74	103½ to	119	25½	to 250	—
Headon Beds	—	—	—	—	—	—	—	—	—	—	—	—	121½	—	—	—	—	—	—	—	—	—	—	99½	169½	204	—		—
Headon Limestone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upper Bagshot or Barton Sand	—	—	—	—	—	128½	—	—	—	—	—	—	105	105	72	—	—	—	—	—	—	—	—	—	—	to 14	—	—	—
Barton Clay	—	—	—	—	—	—	—	—	—	—	—	—	125 to 43	227 to 124	349 to 55	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bracklesham Beds	—	—	—	53	—	31¼	—	—	—	—	48½ to 348	— to 313				41	more than 260 to 11	163½ to 25½	—	291	99	—	—	—	—	—	—	—	to 471½
Lower Bagshot Sand	15	40	—	115[1] to	—	62 to	—	—	—	6			—	—	—	32½			—	25		—	—	—	—	—	—	—	—
London Clay	241	335½ to	247½	332	327	31	—	—	—	118½	—	—	—	—	—	301	—	166	64	327	300	118	221	—	—	—	—	—	—
Woolwich and Reading Beds	80 to	411½	68½ to	—	84 to	—	—	—	—	73½ to	—	—	—	—	—	85	—	—	97 to	130 to	126 to	122[5] to	120 to	—	—	—	—	—	—
Upper Chalk	594	—	216	—	257	—	—	—	—	7	—	—	—	—	—	to 853	—	—	59¾	9	70	109	302	—	—	—	—	—	—
Middle Chalk	—	—	—	—	—	—	268	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Lower Chalk	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upper Greensand	—	—	—	—	—	—	80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gault	—	—	—	—	—	—	192[2]	236½[3] to 8½	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Folkestone Beds	—	—	—	—	—	—	—		69 to 27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sandgate Beds	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hythe Beds	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				

[1] The uppermost 35 feet may be Bracklesham Beds.
[2] Possibly including some Lower Greensand.
[3] Total thickness estimated at over 250 feet.
[4] Identification as Bracklesham Beds doubtful.
[5] Base of Reading Beds not fixed precisely.

To face page 68.

LANCASHIRE.

Table of Strata.

		Thickness in feet.
Superficial ..	Blown Sand, Peat and Alluvium ...	up to 78
	Glacial Drift	up to 240
Triassic ...	Bun- Keu- per. Keuper Marl	1,000
	Lower Keuper Sandstone ...	400
	ter. Upper Mottled Sandstone ...	550
	Pebble Beds	1,200
	Lower Mottled Sandstone ...	400
Permian ...	Marls with limestones and gypsum ...	0–300
	Soft sandstones...	0–1,300
Carboniferous, &c.		—

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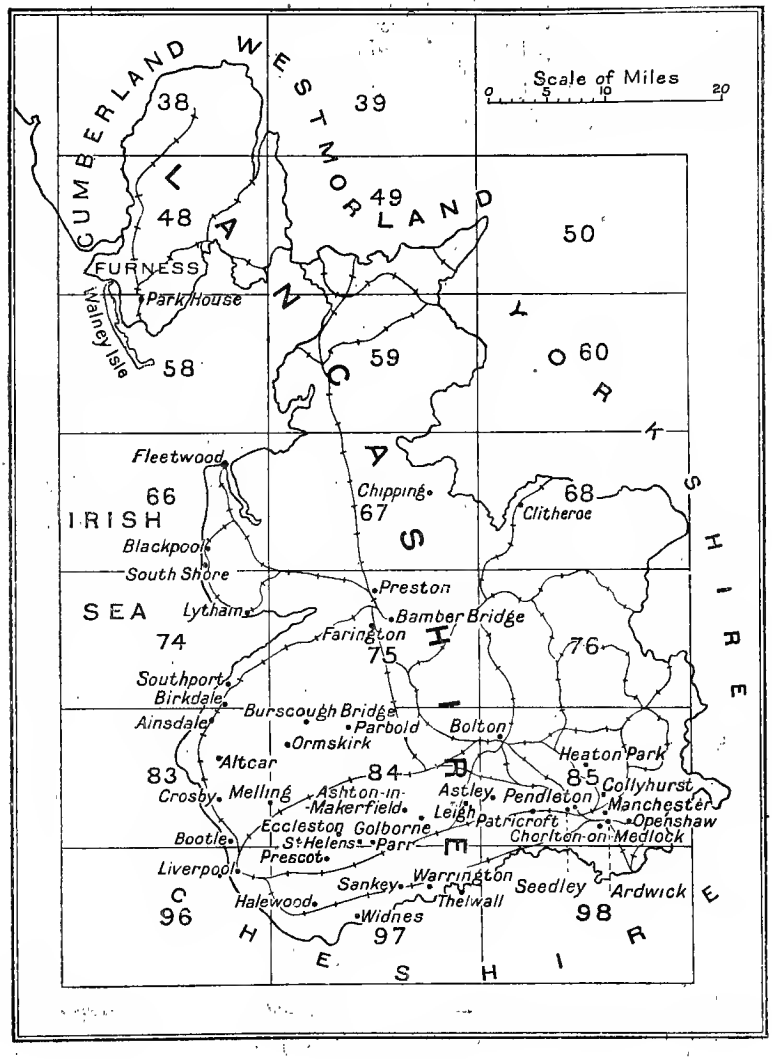
SUPERFICIAL.

Blown Sand, Peat and Alluvium.

That part of the area of Lancashire where Triassic rocks outcrop, that is, in the south and west and in Furness, is mostly covered with glacial and post-glacial deposits. Blown sand occurs along the coast from Liverpool to Southport, from Lytham to Blackpool and Fleetwood, and on Walney Island. The dunes rise to a height of 20 to 30 ft. near Fleetwood (5, p. 12); between Lytham and South Shore they seldom exceed 30 ft. (3, p. 13), but between Ainsdale and Birkdale they reach 40 ft. Southport is built on blown sand, and in a boring in search of water at the Palace Hotel, Birkdale Park, 78 ft. of sand, blown and sedimentary, and 1 ft. 6 ins. of peat and 'Cyclas' clay were found resting on Keuper Marls (3, pp. 4 and 14). Behind the sand-dunes a considerable

area is covered with freshwater clays, peat, and alluvium. The peat varies in thickness from 1 to 30 ft. and more, and runs down to 50 and 60 ft. below sea-level (5, p. 1). The alluvium, clays and blown sand (Shirdley Hill Sand) all vary indefinitely in thickness. (See 7 for local data.)

FIG. 15. LANCASHIRE.



Glacial.

The Glacial Drift consists of boulder-clay, generally a tough red deposit, and of beds of sand intercalated in the clay. It rests upon an undulating rock-surface and varies greatly in thickness. Near Blackpool boulder-clay forms cliffs ranging from 50 to 75 ft. in height, while the rock-surface sinks to at least 20 ft. below sea-level (5). In the area between Preston, Southport and Lytham

the drift rests upon a surface of Triassic rocks which dips gently towards the sea, sinking from 20 ft. above sea-level at Preston to 50 ft. below it at Southport (3). In the Liverpool district the thickness of drift is very variable; it reaches 80 ft. at Edgehill.

Locally great thicknesses of glacial drift have been encountered, as shown in the Table following p. 78. Among other notable records mention may be made of a thickness of 137 ft. at Hunts Cross, Halewood,[1] 146½ ft. at Watling Street Road, Preston,[2] more than 112½ at Bashall's Mill, Farington,[3] and 146½ ft. near Bamber Bridge.

It has been shown by borings in Widnes and Warrington[4] that a deep valley, filled up with drift, exists north of the present course of the Mersey. This gorge descends to more than 140 ft. below sea-level, there being 163¼ ft. of drift at Lambert's Copper Works, Widnes, 198 ft. at Gaskell, Deacon and Co.'s works 200 yards from the station, and at N. Mathieson and Co.'s, 136 ft. 10 ins. (9, pp. 23-24). At Sankey Bridge, near Warrington, water was obtained from a bed of gravel below 100 ft. of drift.[5] The greatest depth was found at Wildgreave Farm, opposite Thelwall, Warrington, where the rock was not reached after boring through 231 ft. of superficial deposits.[6]

A good example of the unevenness of the pre-glacial surface of the rock was proved in borings at Park House, Iron Mines, in Furness. Within an area 400 yds. by 200 yds., twelve borings were made. The 'panel,' or boulder-clay, showed the following thicknesses in ft., in the twelve borings:—36, 39, 51, 306, 162, 225, 195, 114, 249, 369, 88, 537. A fault was proved in the rocks beneath to throw in softer rocks on its western side. It was on this side that the drift attained the greater thicknesses (4, pp. 4, 5, with map).

Triassic.

The thickness of the Triassic Rocks in Lancashire is for the most part a matter of conjecture. The thicknesses given on p. 75 are estimates made by the late G. H. Morton for the neighbourhood of Liverpool, with the exception of the figure given for the Pebble Beds, which is founded on the borehole at Bootle, quoted in the table of borings. The greatest thickness of marl in one bore is recorded from Altcar as 971 ft., where, however, the top was absent (10). At the Palace Hotel, Southport, a boring made in an unsuccessful attempt to get water proved 479⅓ ft. of marl under 79½ ft. of superficial deposits (3, pp. 4 and 14), and at Fleetwood 428⅓ ft. of marl were traversed without reaching the base.

The Keuper Sandstone and Upper Mottled Sandstone are only partly visible and no precise information regarding their thickness in the country between Crosby, Ormskirk and Preston is available. The Pebble Beds were penetrated for a distance of

[1] *Rep. Brit. Assoc.* for 1889, pp. 76, 77.
[2] *Rep. Brit. Assoc.* for 1881, p. 315.
[3] *Rep. Brit. Assoc.* for 1887, p. 380.
[4] T. Mellard Reade. The Buried Valley of the Mersey. *Proc. Liverpool Geol. Soc.*, vol. ii, sess. xiv (1873), pp. 42-65.
[5] *Rep. Brit. Assoc.* for 1876, p. 105.
[6] *Ib.*, 1891, p. 306.

1,026 ft. in the Bootle Bore before the supposed Lower Mottled Sandstone was reached.[1] The boring started about 180 ft. below the top, and thus showed that the total thickness of Pebble Beds at Bootle is not less than 1,206 ft., as compared with 934 ft. at Heswall in Wirral (p. 31). At Pendleton their thickness was estimated by Binney at 900 ft., but in the Bolton district 500 to 600 ft. is given as the average figures (1, pp. 22, 23). Near Prescot they are supposed to be 600 to 800 ft. thick (9, p. 12), but may probably be more. The Lower Mottled Sandstone does not exceed 250 ft. at Parr and is less at Eccleston Hall where it rests directly on the Coal Measures (9, p. 12). It was estimated by Morton to be 400 ft. thick near Liverpool, but it must be remembered that it was proved in the Heswall boring, 10 miles to the S.S.W. of Liverpool, to be no less than 1,272 ft. thick.

Permian.

This formation consists of an upper marly series with thin layers of limestone and gypsum, with a maximum thickness of 300 ft., and a lower member of soft sandstone with a maximum thickness of 1,300 ft. The greatest thickness is attained in the neighbourhood of Manchester and Stockport (Cheshire). At Openshaw the Permian strata have a total thickness of 1,322 ft. (12), and at Heaton Park of 1,094¼ ft.,[2] but at the intermediate localities of Chorlton-on-Medlock and Ardwick they are only 300 and 353 ft. thick, and at Patricroft only 92 ft. (12). The development westwards from Manchester is shown by the sections at Seedley Print Works,[3] Astley and Edge Green, quoted in the following table. At Ashton-in-Makerfield the thickness is 187 ft., but westward of St. Helens the Permian is not recognised as such, and the Lower Mottled Sandstone comes to rest upon the Carboniferous strata, occupying a position corresponding in this respect to the Permian sandstone of the more eastern tract.

In Furness a red sandstone has been proved to be more than 330 ft. thick (4, p. 5). It lies above a fossiliferous magnesian limestone of Permian age, which is about 63 ft. thick (4, p. 9) and rests upon Carboniferous rocks. The red sandstone was formerly referred to the Upper Permian, but is correlated with the St. Bees Sandstone, now regarded as Bunter. There is a small inlier of Permian rocks in Skillaw Clough, near Parbold. The Magnesian Limestone and Permian sandstone together do not exceed 300 ft. in thickness.[4]

Small exposures also occur near Preston and near Clitheroe. At the former they have been estimated to be not more than 250 ft. thick.[5]

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[1] *Rep. Brit. Assoc.* for 1878, pp. 395-7; for 1880, pp. 87, 88; for 1889, p. 76.
[2] J. Dickinson. *Trans. Manchester Geol. Soc.*, vol. xxviii, 1903, p. 69.
[3] *Rep. Brit. Assoc.* for 1887, p. 377.
[4] 'Geology of the Country around Wigan,' *Mem. Geol. Surv.*, 1860, p. 24.
[5] 'Geology of the Burnley Coalfield,' *Mem. Geol. Surv.*, 1875, pp. 120-121.

To face page 78.

PRINCIPAL BORINGS, &c., LANCASHIRE.

	Fleetwood Barracks.[1]	Altcar.	Bootle.	Burscough Bridge.	Melling.	Edge Green, near Ashton-in-Makerfield.	Bedford Brewery, Leigh.	Astley.	Heaton Park.	Seedley Print Works.	Deacon's Brewery, Ardwick.	Clayton Colliery, Openshaw.	Medlock Vale.	Lambert's Copper Works, Widnes.	Gaskell & Co., Widnes.	Wildgreave Farm, opposite Thelwall, Warrington.
	Ft. in.	Ft.	Ft.	Ft.	Ft.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in. to	Ft.	Ft. to
Superficial Deposits	59 2	58	—	240	24	33 0	9 6	118 1	142 11	61 0	?	36 0	26 0	163 3	198	231
Keuper—																
Marls	to 428 4	971	—	26 ?	—	—	—	—	—	—	—	—	—	—	—	—
Sandstone	—	to 62	—	185 ?	—	—	—	—	—	—	—	—	—	—	—	—
Trias Bunter—																
Upper Mottled Sandstone ...	—	—	—	—	101 to 436				353 4							
Pebble Beds	—	—	1026 to 274	—		94 11	244 6	480 4		139 0	131 6	46 2	23 0	—	tou hed	—
Lower Mottled Sandstone ...	—	—		—	—				—							
Permian Marls	—	—	—	—	—	181 11	to 253 10	130 10	242	128 0	167 6	954 10	245 6	—	—	—
Sandstone	—	—	—	—	—			65 0 to	852 1 to	12 6 to	184 0 to	to	423 10 to	—	—	—
Carboniferous...	—	—	—	—	—	172 3	—	919 3	781 8	30 0	6 9	263 0	90 0	—	—	—

[1] From a MS. Section. The version does not agree with that published in the *Brit. Assoc. Rep.* for 1890.

LEICESTERSHIRE AND RUTLAND.

Table of Strata.

		Thickness in Feet.
Superficial	Alluvium	up to 30
	Glacial Deposits	up to 150
Oolitic	Cornbrash	5–15
	Great Oolite Clay	20–30
	Great Oolite Limestone	30–35
	Upper Estuarine Series	15–30
	Lincolnshire Limestone	30–120
	Northampton Sands	0–30
Liassic	Upper Lias	80–200
	Middle Lias	60–120
	Lower Lias	650–750
Triassic	Rhaetic	16–38
	Keuper: Upper Keuper Marls, &c.	up to 525
	Keuper: Lower Keuper Sandstones	up to 330
	Bunter	0–1,000
Permian (so-called)		0–50
Carboniferous and older rocks		—

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1. The Geology of Rutland, *Mem. Geol. Surv.*, 1875.
2. *Rep. Brit. Assoc.* Reports of the Committee to investigate the Circulation of the Underground Waters, &c, 1875–1895.
3. The Geology of S.W. Lincolnshire, &c., *Mem. Geol. Surv.*, 1885.
4. The Jurassic Rocks of Britain, *ib.*, vol. iii, 1893.
5. ,, ,, *ib.*, vol. iv, 1894.
6. The Geology of the Country between Atherstone and Charnwood Forest, *ib.*, 1900.
7. The Geology of the Country near Leicester, *ib.*, 1903.
8. The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch and Loughborough, *ib.*, 1905.
9. The Geology of the Melton Mowbray District, *ib.*, 1909.

SUPERFICIAL.

Recent.

The Alluvium and valley-gravels along the principal streams, the Soar and the Wreak, range in thickness from 4 or 5 ft. to 30 ft. or more (8).

Glacial.

The Glacial Deposits are thicker and more important east of Leicester and the Soar valley than in the western half of the county. They fill and level up minor irregularities of the pre-glacial surface and reach a thickness of at least 150 ft. in the old hollows (6). Around Melton Mowbray also they are 200 ft. thick in places (1). A boring at Garthorpe, near Waltham-on-the-Wolds, traversed at least 50 ft., but along the Rutlandshire border the thickness seldom exceeds 10 ft.

Near Loughborough and in Leicester glacial drift ranges from 8 to 30 ft. (2).

At Rotherby the boulder-clay and associated sands were found to be at least 26 ft. thick, whilst further east at Hallaton a well is said to have been sunk to a depth of 150 ft., the 'spoil-heap' consisting of boulder-clay only (2).

At Fleckney a well showed 30 ft. of boulder-clay resting on 15 ft. of sand and gravel.

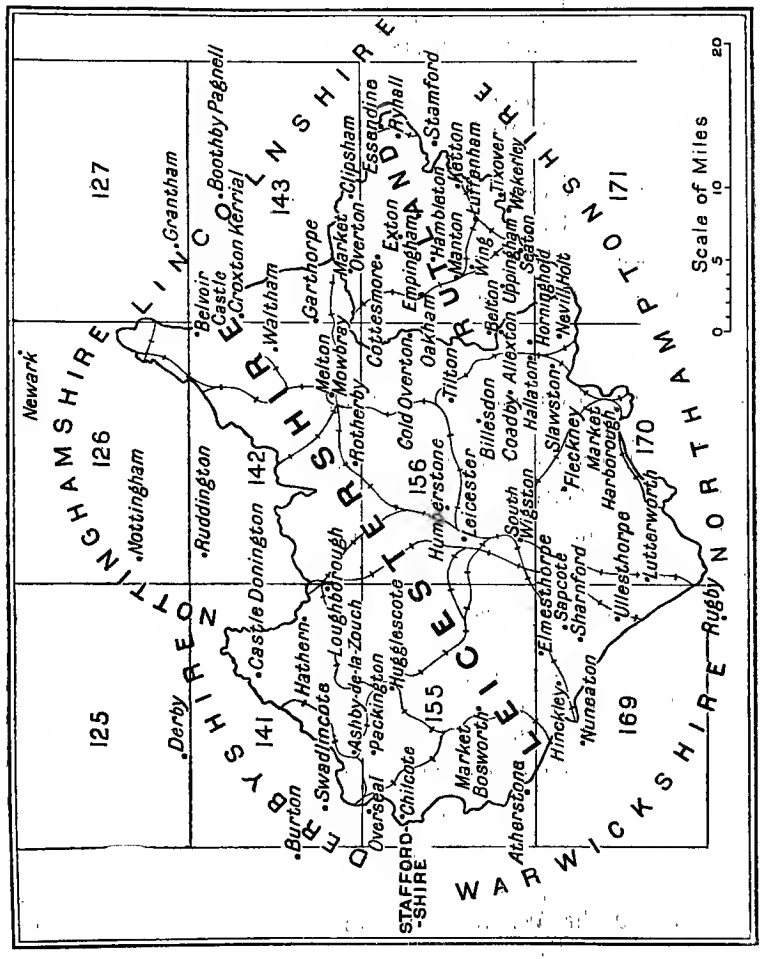


Fig. 16. Leicestershire and Rutland.

There also appears to be a thick sheet of boulder-clay in the south-west of the county from the neighbourhood of Market Bosworth southwards. Thus, a well at Hugglescote showed over 30 ft. of boulder-clay resting on gravel; a boring to the immediate north-east of Market Bosworth showed 40 ft. of boulder-clay; another at Bosworth Wharf 27 ft.; and another at Kingshill over 100 ft. (6). At Osbaston, near Market Bosworth, a brickearth free from stones extended to a depth of 40 ft. below the present valley (6).

All around Hinckley the boulder-clay appears to be thick, the pre-glacial valleys being fully 60 ft. deep below the general level of the country. Two borings at Hinckley showed the glacial beds to be 90 and 150 ft. respectively, while at Sharnford, five miles to the south-east of Hinckley, they were at least 80 ft. thick (2).

In the Lutterworth district about 50 ft. is the recorded thickness at Ullesthorpe, three miles north-west of the town.

Oolitic.

Cornbrash.

Cornbrash forms three small outliers in Rutlandshire, viz., north of Clipsham, south of Ryhall, and Luffenham Heath. It never exceeds 15 ft. in thickness and is often much less (1).

Great Oolite Clay.

This subdivision is represented in small outliers on the eastern borders of Rutlandshire and also at Luffenham Heath in the same county close to the River Welland. It attains a maximum of 20 to 30 ft. (1).

Great Oolite Limestone.

This rock forms numerous outliers in East Rutland. In the railway-cutting at Essendine it is 30 to 35 ft. thick, and this appears to be the average development in the district (1).

Upper Estuarine Series.

The lowest subdivision of the Great Oolite, like the others, is represented in East Rutlandshire only. It almost invariably has a conspicuous band of ironstone nodules at the base and its total thickness probably never exceeds 30 ft. and often is much less (1).

At Ketton and near Stamford and Grantham (Lincolnshire) it varies from 20 to 30 ft.

Lincolnshire Oolite.

This rock appears in North Northamptonshire as a wedge between the Lower and Upper Estuarine Series and rapidly thickens in a northerly direction, forming a conspicuous escarpment in Rutland and Lincolnshire. In Leicestershire it is only represented in detached outliers along the eastern borders of the county and to the north of Melton Mowbray. Across the Rutland border at Wakerley on the Welland it is 30 ft. thick, rapidly expanding eastwards to 74 ft. at Stamford (1). East of Empingham a thickness of 60 ft. 9 ins. is recorded in Lincolnshire. In the neighbourhood of Waltham-on-the-Wolds it is not fully developed and may be 20 to 30 ft. (9), but its full thickness cannot be less than 100 to 120 ft., and as much as 132 ft. has been recorded from a well-boring at Boothby Pagnell in Lincolnshire.

Northampton Sands.

These beds are subdivided into a lower part consisting of ferruginous sandstone and ironstone, and an upper series of sands and clays frequently termed the Lower Estuarine Series.

At Nevill Holt, near Market Harborough, the Northampton Sands are about 20 ft. thick (1), and are no less at Uppingham and Bisbrooke: also at Seaton and Morcot. On the south of the River Welland, at Wakerley, the lower bed of ironstone is 9 ft. thick and the overlying sands and clay 7 ft. From here the Northampton Sands thin rapidly eastwards to only 2 or 3 ft. and finally disappear near Tixover where the Lincolnshire Limestone rests on the Lias clays. At Luffenham the total thickness is not more than 10 ft. Westwards at Pilton and Wing there are about 15 to 20 ft. of these sands and at Manton only 4 ft. Around Edithweston, Whitwell and Exton they range from 10 to 20 ft. At Stamford the ironstone is 16 ft. thick and the overlying sands 8 ft. At Ketton the ironstone is 18 ft. and the overlying sands 9 ft. Around Cottesmore and Market Overton the total is at least 20 ft.

Further north around Waltham the Northampton Sands are 20 to 30 ft. thick, but at Croxton Kerrial only 12 ft. (3).

Liassic.

In Rutland the Upper Lias does not exceed a thickness of about 200 ft. Thus it was found to be 193½ ft. thick at Stamford in Lincolnshire and 176 ft. at Hambleton. In the west of the county it is not more than 110 to 120 ft. thick below the outliers of Inferior Oolite at Ranksborough and Whatborough Hill; and 180 ft. below Robin-a-Tiptoes and at Belton (7). In Leicestershire it ranges between 110 and 180 ft., and near Melton Mowbray and Grantham averages about 120 ft. (3).

The Middle Lias consists of two subdivisions:—

Marlstone, calcareous sandstone passing into ironstone.
Lower clays, and shales with bands of limestone.

In the south both are thin, and at Market Harborough the marlstone is absent. On the south side of Slawston Hill it is scarcely traceable, and the Middle Lias as a whole has a thickness of 60 to 70 ft. (4). Northwards of Hallaton the marlstone is less than a foot in thickness, 2 ft. thick at Godeby and Horninghold, 2½ ft. at Allexton (1), 6 or 8 ft. around Oakham and Barleythorpe and 9 ft. at Langham (1). In a boring near Oakham, however, the Marlstone rock-bed is 18 ft. thick, and at Hambleton, to the east, 15 ft.

Between Leicester and Oakham at Tilton-on-the-hill and Somerby the marlstone is 18½ ft. thick, while it appears to be still thicker about Billesdon and Burrow-on-the-hill (1). In the Melton Mowbray district it reaches 30 ft. and maintains this thickness to the county boundary (3).

The underlying Middle Lias clays correspondingly expand in a northerly direction and reach a thickness of about 100 ft. in the Melton Mowbray district, but further north, in Lincolnshire (3), they do not exceed 40 ft.

The Lower Lias in the south of Leicestershire may be upwards of 750 ft. thick. In the neighbourhood of Melton Mowbray it appears to be about 650 ft. and in the Vale of Belvoir 670 ft. (9). A boring close to Billesdon, commencing in the Lower Lias, proved the thickness to exceed 600 ft. (1).

Triassic.

Rhaetic.

The Rhaetic group includes 'White Lias' Marls with interbedded bands of limestone, and below these black paper-shales.

These beds have not been traced south of Wigston though there is no doubt they occur some distance to the west of Lutterworth under drift gravels. South of Leicester, at South Wigston, the White Lias is 20½ ft. thick and the shales below 17 ft. At Humberstone the Rhaetic beds are about 20 ft. thick (7), and near Melton Mowbray average about 32 ft., of which 12 to 18 ft. are assignable to White Lias (9). Approximately the same thicknesses are found across the northern border of Leicestershire.

Keuper.

Upper Keuper Sandstone.
Keuper Marl.
Lower Keuper Sandstones and Waterstones.

The Upper Keuper Sandstone is but locally developed.

The Keuper Marl covers the greater part of Leicestershire west of Leicester and overlapping the Lower Keuper Sandstone abuts directly on the old rocks. The rock-floor on which it rests is most irregular in form. In the extreme south-west of Leicestershire a boring at Hinckley showed 12 ft. of Upper Keuper Sandstone and 396 ft. of Keuper Marl on Lower Keuper sandstones and marls which were bored through to a depth of 303 ft. (2). At Sapcote Freeholt, 2 miles east of Hinckley, a boring (by some referred to as 'Elmesthorpe') was commenced in Keuper Marl, proved the thickness at that spot to be 470 ft. The marl was conglomeratic at its base for a few inches and rested on Coal Measures, underlain by Cambrian Rocks.[1] At Market Bosworth the Keuper beds were found to be 744 ft. thick, with 10 ft. of breccia at their base. Of these the upper 370 ft. appear to be referable to the Keuper Marl. Around Leicester the Keuper reaches a thickness of about 700 ft., of which about 100 ft. may be classed with the Lower Keuper Sandstone. A deep boring near the town showed 525 ft. of Keuper Marls underlain by 106 ft. of Keuper Sandstone resting on black slaty rocks (7). The variable thickness of these beds is shown by the record of a boring at Humberstone where the full thickness of the Upper Keuper Sandstone is 100 ft., of the Upper Keuper Marl 250 ft., and of the Lower Keuper Sandstones 232 ft. (2). A still further variation is shown by the boring at Hathern, near Loughborough. Here, under Keuper Marl, Lower Keuper Sandstone, 140 ft. thick, rests on Bunter (2 and 8). Near Melton Mowbray only the upper part of the Keuper Marl is represented, and the maximum thickness is at least 630 ft.

Bunter.

The Pebble Beds only are represented, and they occur at a few isolated places around the western part of the Leicestershire coalfield. They probably have a maximum thickness of about 1,000 ft.,

[1] *Quart. Journ Geol. Soc.*, vol. xlv, 1889, pp. 29, 30.

959 ft. having been proved at Chilcote[1] in Derbyshire just across the county boundary. To the east, however, they gradually thin away and were probably more continuous to the east of a line drawn through Castle Donington and Ashby. In a boring at Hathern, however, near Loughborough, a thickness of 60 ft. has been doubtfully assigned to them (8).

Permian (so-called).

Small outliers of so-called Permian occur close to the Coal Measures on the western borders of Leicestershire and may reach 50 ft. in thickness at a maximum. Their outcrop is most irregular and they appear to occur principally along hollows in the underlying Carboniferous rocks. In the Swadlincote district, north-west of Ashby, the average thickness of the marls and breccias provisionally termed Permian appears to be about 15 ft., and the same thickness has been proved in a boring at Overseal, five miles to the south-west of Ashby-de-la-Zouch. The thickest beds of breccia are stated to be those around Packington.

[1] 'Geology of the Leicestershire and South Derbyshire Coalfield,' *Mem. Geol. Surv.*, 1907, pp. 331-332. In Fig. 16 Chilcote has been inserted by error on the Leicestershire side of the county boundary.

PRINCIPAL BORINGS IN LEICESTERSHIRE AND RUTLAND.

(Thicknesses in feet and inches.)

		Hathern.	Melton Mowbray.	Bosworth Wharf.	King's Hill Spinney, near Market Bosworth.	Humberstone.	Leicester (Crown Hill).	Oakham.	Hambleton.	Sapcote Freeholt.	Hinckley.
		Ft.	Ft.	Ft.	Ft.	Ft.	Ft. in.	Ft.	Ft. in.	Ft.	Ft.
Superficial	Alluvial	—	—	—	—	—	—	—	—	—	1
	Glacial Deposits	10	149	27	100	6	—	4	—	10	88
Oolitic ...	Lincolnshire Limestone ...	—	—	—	—	—	—	—	—	—	—
	Northampton Sands ...	—	—	—	—	—	—	—	10 6	—	—
Liassic ...	Upper Lias	—	—	—	—	—	—	30	176 0	—	—
	Middle Lias	—	—	—	—	—	—	to 46	to 49 0	—	—
	Lower Lias	—	212	—	—	—	—	—	—	—	—
Triassic...	Rhaetic	—	26	—	—	12	16 9	—	—	—	—
	Upper Keuper Sandstone	—	} to 170	} 754 (breccia 10)	—	100	—	—	—	—	12
	Keuper Marl	110			372	250	525 2	—	—	470	396
	Lower Keuper Sandstone	140			} 476	to 232	106 0	—	—	—	to 309
	Bunter	} 619	—			—	—	—	—	—	—
Carboniferous and other Rocks ...			—	to 610	to 206	—	to 163 0	—	—	to 980	—

LINCOLNSHIRE.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Alluvium	upwards of 60
	Glacial	up to 166
Cretaceous	Upper Chalk	not known.
	Middle Chalk	80–100
	Lower Chalk	75–80
	Red Chalk	4–12
	Carstone	up to 40
	Tealby Limestone and Ironstone	up to 40
	Tealby Clay with Claxby Ironstone	up to 190
	Spilsby Sandstone	6–50
Oolitic	Kimmeridge Clay	up to 320
	Corallian Clay	15–20
	Oxford Clay	300–450
	Kellaways Beds	7–25
	Cornbrash	3–15
	Great Oolite Clay	5–35
	Great Oolite Limestone	12–25
	Upper Estuarine Series	20–35
	Lincolnshire Limestone	36–132
	Lower Estuarine Series	up to 15
	Northampton Beds or Dogger	2–35
Liassic	Upper Lias	25–200
	Middle Lias	40–100
	Lower Lias	290–765
Triassic	Rhaetic	about 25
	Keuper Marls and Waterstones	900–1,000

Proved in borings only :—

Triassic	Bunter	800
Permian	Limestones and marls	545
Carboniferous Rocks		—

1. Geology of the Country around Lincoln, *Mem. Geol. Surv.*, 1888.
2. Jurassic Rocks of Britain, *ib.*, vol. iii, 1893.
3. ,, ,, *ib.*, vol. iv, 1894.
4. ,, ,, *ib.*, vol. v, 1895.
5. Cretaceous Rocks of Britain, *ib.*, vol. i, 1900.
6. ,, ,, *ib.*, vol. ii, 1903.
7. Water Supply of Lincolnshire, *ib.*, 1904.
8. A. J. Jukes-Browne. Geology in the Field, *Geol. Assoc.*, 1910, p. 488.
9. B. Smith. *Geol. Mag.* for 1912, p. 252.

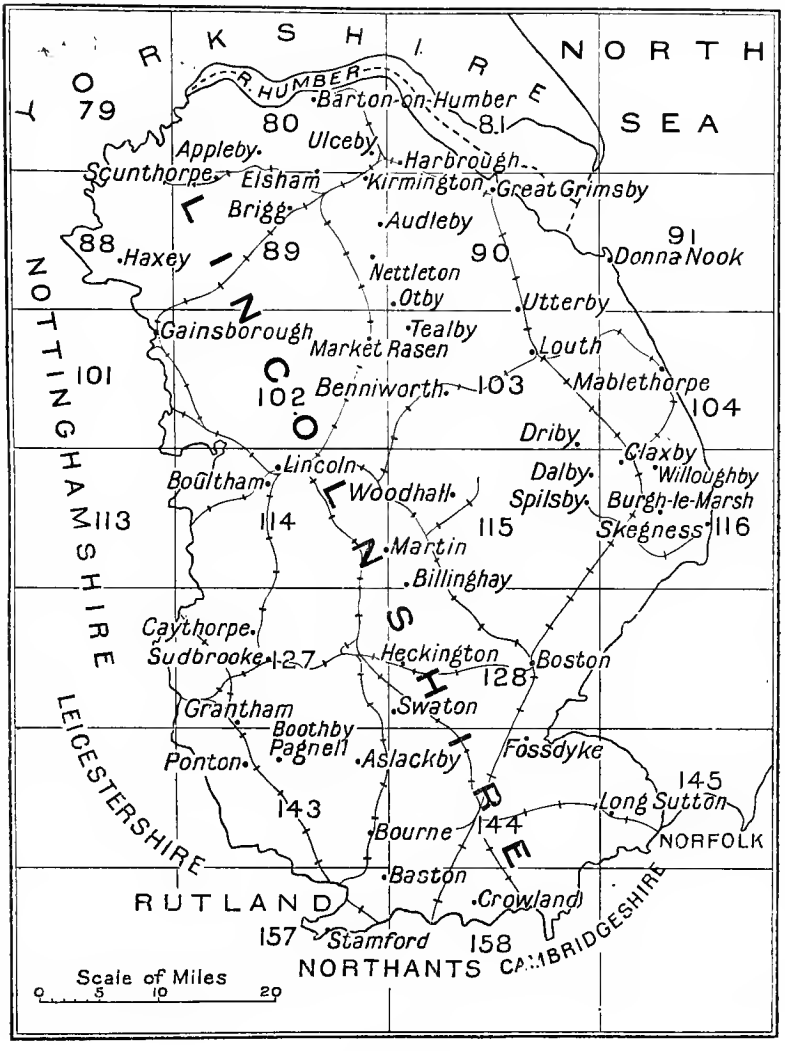
Superficial.

Alluvium.

Alluvium and valley-gravels cover over 47 per cent. of the area of Lincolnshire.

Much of the alluvial land is below high tide level. It is composed of peat, clay, marl and silt, generally about 20 ft. thick, but in places, such as Long Sutton, Mablethorpe and in the lower parts of the Trent Valley, exceeding 60 ft.

FIG. 17. LINCOLNSHIRE.



Glacial.

The glacial deposits consist of boulder-clays and gravels, and cover 20 per cent. of the surface area of the county. They are developed chiefly in the depression between the Oolitic and Cretaceous escarpments, on the east of the Chalk Wolds and under the alluvial deposits of the Fen country.

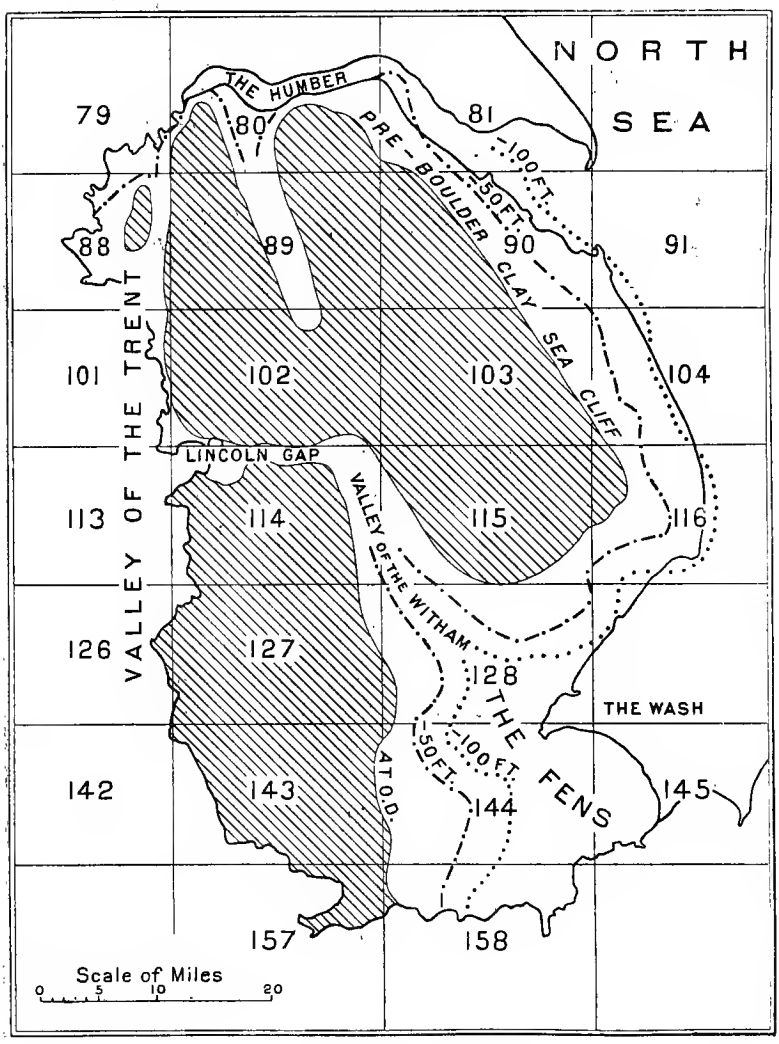
A pre-boulder-clay sea-cliff runs from Barton-on-Humber past Ulceby and south-east to Utterby and from thence about two miles east of Louth to Willoughby. To the east of this line the drift has a thickness ranging from 50 ft. near the cliff to 100 ft. on the coast.

Under the Fen country bordering the Wash the boulder-clay is over 100 ft. thick, a fact which has been proved at Boston,

Fossdyke, Crowland and Long Sutton. In the valley of the Witham also the rock-surface lies below sea-level, so that if the drifts were removed the sea would flow into the valley of the Trent through the Lincoln Gap (1), as shown in Fig. 18.

There seems also to be a buried channel cutting across the Wolds from Habrough (Harbrough on Fig. 17) to Kirmington, at both of which places there is a great thickness of drift.

FIG. 18. MAP OF LINCOLNSHIRE, showing contours in the rock-surface below sea-level.
(In the shaded area the rock-surface is above sea-level.)



CRETACEOUS.

Chalk.

Of the Upper Chalk the lower part only exists in Lincolnshire. The Middle Chalk is from 80 to 100 ft. thick, 70 to 80 ft. being

assignable to the *Terebratulina* Zone and 10 to 13 ft. to that of *Rhynchonella cuvieri* (6).

The Lower Chalk is from 75 to 80 ft. thick, compared with 55 ft. in North Norfolk, the chief increase being in the lower parts of the *Ammonites varians* Zone (6).

The Red Chalk has a thickness of 12 ft. at the south end of the Lincolnshire Wolds, but at the north end it has thinned to 4 or 5 ft. (1 and 5).

The Lower Cretaceous Series includes:—

Carstone or Ferruginous Sand.

Tealby Beds ... { Tealby Limestone with an Upper Ironstone 'roach'.
Tealby Clay with the Claxby Ironstone.

Spilsby Sandstone, a hard grey calcareous rock, usually weathered to a loose brown and white sand.

All these bands, with the exception of the Tealby Limestone, attain their greatest development at the south end of the Wolds and thin steadily northwards. The limestone, however, is doubtfully represented in the south by 40 ft. of 'roach,' and only becomes a distinct rock-bed from near Donnington northwards.

The Carstone is 40 ft. thick in the south but disappears before reaching the Humber (1).

The Tealby Beds are 219½ ft. thick at Skegness, and of this 191 ft. may be assigned to the Tealby Clay (7). At the outcrop further west the clay is 100 ft. thick, and thence northwards towards Tealby it attenuates to 26 to 30 ft. (1). The Tealby Limestone ranges from 10 to 15 ft. in thickness near Tealby and Claxby, but is less further north. The Spilsby Sandstone thins northwards along the outcrop and also south-eastwards; at Skegness it appears to have been only 26 ft. thick (7):—

	South end of Wolds.	Tealby.	Otby.	Claxby.	Acre House, Nettleton.	Nettleton.	Audleby.	Melton Ross.	Elsham.
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Red Chalk ...	11	6	6	5	?	4	4	½	3–4
Carstone ...	40	25	20	14	10	8	0	0	⅛
Tealby Beds ...	135	65	60	60	68	20–40	10	0	1–3
Spilsby Sandstone	50	42	(about) 36 (about)	30	(?) 7	35	15	9 (about)	10

Oolitic.

Kimmeridge, Corallian and Oxford Clays with Kellaways Beds.

These formations underlie the alluvial tracts of the Fens and the Ancholme Valley. The thickness of the Kimmeridge Clay is estimated at 320 ft. (7). The Corallian is represented by some 20 ft. of black clay with much selenite, while the Oxford Clay is about 300 ft. thick in North Lincolnshire and over 450 ft. in the south of the county. At Woodhall a boring, starting in superficial deposits, passed through 468 ft. of Kimmeridge and Oxford

Clays into the Kellaways Beds (7). It is believed that there may be about 800 or 900 ft. of clay between the Spilsby Sandstone and the Kellaways Beds.

The Kellaways Beds, at the base of the Oxford Clay, consist of an alternating series of buff sandstones, sands, loams and clays, with usually clay or shale from 7 to 18 ft. thick at the base. The full thickness at Sudbrooke is about 25 ft. (7).

Cornbrash.

The Cornbrash is a fossiliferous rubbly limestone averaging about 7 ft. thick (4, 7) in Central Lincolnshire, but thinning northwards to about 3 ft. Southwards it increases to about 15 ft. at Stamford.

Great Oolite Clay and Limestone.

The Great Oolite Clay consists of dark-gray, purple and greenish clays with oyster-beds and lignite. It ranges from 5 to 35 ft. in thickness.

The Great Oolite Limestone comprises hard shelly and occasionally oolitic limestones with shales and marls. The aggregate thickness varies from 12 to 25 ft., but the formation disappears to the north of Brigg and is not persistent as a limestone under the Fenland.

The Upper Estuarine Series and Lincolnshire Limestone.

The Upper Estuarine Series consists of white sands, green clays, with shelly marls and limestones, and is from 20 to 35 ft. thick.

The Lincolnshire Limestone, an oolitic rock which forms a notable source of artesian water in South Lincolnshire, becomes less homogeneous in North Lincolnshire, where it includes an upper part of oolitic limestone (Ponton Beds) about 20 ft. thick, and a lower part, about 45 ft. thick, in which clays appear. The aggregate thickness ranges from 36 ft. at Crowland to 132 ft. at Boothby Pagnell. At Lincoln it has thinned to 70 ft., and further north to 60 ft. (8).

The Lower Estuarine Series and Northampton Beds or Dogger.

The Lower Estuarine Series and Northampton Beds or Dogger vary from about 10 ft. up to 35 ft. The beds are worked for ironstone in places. In the central parts, near Lincoln, the Estuarine beds are practically absent, while in the north of the county the Dogger and some white sands measure from 20 to 30 ft. in thickness (8).

Liassic.

The Upper Lias of North Lincolnshire does not exceed 26 ft. at Appleby, but thickens southwards to 80 ft. at Lincoln, 120 ft. near Grantham, 135 ft. at Crowland, and 200 ft. at Caythorpe (7, 8).

The Middle Lias comprises a lower clay-zone from 40 to 80 ft. thick and an impersistent upper sandstone- and ironstone-group. This rock-bed or marlstone is 30 ft. thick near Grantham (7), but at Lincoln is represented by a single layer of stone which thickens

PRINOIPAL BORINGS IN LINCOLNSHIRE.

(Thicknesses in feet.)

	Stamford.	Crowland.	Baston.	Bourne.	Aslackby.	Boothby Pagnell.	Long Sutton.	Grantham.	Swaton.	Boston.	Heckington.	Martin.	Boultham (Lincoln).[1]	Billinghay.	Woodhall.	Skegness.	Burgh-le-Marsh.	Dalby.	Willoughby.	Claxby.	Gainsborough.	Driby.	Benniworth.	Louth.	Mablethorpe.	Haxey.[2]	Brigg.	Scunthorpe.	Appleby.	Barton-on-Humber.
Alluvium	—	14½	} 12	—	13	} 6	57	28	8	24	—	4	} 22	3	—	34	10	—	—	2½	—	—	—	9	56	32	40	} 22½	—	50
Glacial	—	152½		4½	—		100	—	34	166	10	58		60	5	16½	48	—	63	—	—	—	6	—	56	—	—		—	—
Chalk	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	21	—	—	—	10	—	190	—	9	to 2	—	—	—	—	49
Red Chalk	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—	10	—	11	—	11	—	—	—	—	—	—
Lower Greensand—																														
Carstone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	10	—	15	—	to 29	—	—	—	—	—	—
Roach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	28½	—	35	43	14	—	} to	—	—	—	—	—	—	—	—
Tealby Clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	191	—	102	108	40	—	} 120	—	—	—	—	—	—	—	—
Claxby Ironstone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18	14	—	—	—	—	—	—	—	—	—	—
Spilsby Sandstone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26	—	to 58	to 16	7	—	—	—	—	—	—	—	—	—	—
Kimmeridge Clay	—	—	—	—	—	—	to 116	—	—	} 294	—	—	—	—	} 494	to 78	to 154	—	—	to	—	—	to 320	—	—	—	—	—	—	to
Corallian	—	—	—	—	—	—	—	—	—		—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxford Clay	—	41	64	3	61	—	—	—	85		245	167	—	186		—	—	—	—	—	—	—	—	—	—	—	62	—	—	—
Cornbrash	—	6½	7½	8½	4½	—	—	—	3½	} 88	7	6	—	8	6	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—
Great Oolite Clay	—		17½	20	22½	10	—	—	13		22	25	—	21½	26	—	—	—	—	—	—	—	—	—	—	—	24	—	—	—
Great Oolite Limestone ...	—	36	14	12	11	2½	—	—	21		17	36½	—	26	10½	—	—	—	—	—	—	—	—	—	—	—	11½	—	—	—
Upper Estuarine Series ...	—		27½	28	40	20½	—	—	27	—	22	10½	—	15	36½	—	—	—	—	—	—	—	—	—	—	—	24	—	—	—
Lincolnshire Limestone ...	15	36½	to 28	to 56½	to 10	132	—	—	to 58	—	to 77	102½	—	98	68½	—	—	—	—	—	—	—	—	—	—	—	44½	—	37	—
Lower Estuarine Series ...	—	} 21½	—	—	—	—	—	—	—	—	—	—	—	—	to 30½	—	—	—	—	—	—	—	—	—	—	—	—	—	34	—
Northampton Beds	24		—	—	—	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	} 108	—	2	—
Upper Lias	193½	135	—	—	—	to 1	—	—	—	—	—	to 2	—	to 2	—	—	—	—	—	—	—	—	—	—	—	—		—	26	—
Middle Lias	to 61	} to	—	—	—	—	—	} 802	—	—	—	—	} 610	—	—	—	—	—	—	—	—	—	—	—	—	—	to 46	—	78	—
Lower Lias	—	} 160	—	—	—	—	—		—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 110	—
Rhaetic	—	—	—	—	—	—	—	23	—	—	—	—	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	19½	—	—
Keuper Marl and Waterstone ...	—	—	—	—	—	—	—	to	—	—	—	—	907	—	—	—	—	—	—	—	720	—	—	—	—	—	—	1003	—	—
Bunter	—	—	—	—	—	—	—	—	—	—	—	—	to 639	—	—	—	—	—	—	—	to 795	—	—	—	—	} 1151	—	740	—	—
Permian	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	557	—	—	—	—
Coal Measures	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	to 1457½	—	—	—	—

[1] From an unpublished section by Mr. Henry Preston.

[2] The Haxey boring is sometimes referred to as the South Carr on Idlestop boring. It is situated close to the boundary between Lincolnshire and Nottinghamshire. Details as to the divisions of the Permian and Trias will be found in the table following p. 110.

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northwards to 5 ft. The total thickness of the Middle Lias does not exceed 100 ft. (8).

The Lower Lias thickens from 290 ft. in the north of Lincolnshire to about 700 ft. in the south of the county (2, 7).

Triassic.

Rhaetic.

The Rhaetic beds consist of black shales about 25 ft. thick. The boring at Boultham showed 22 ft. of these above the uppermost green marls of the Keuper.

Keuper and Bunter.

The Keuper consists of red and green marls with subordinate sandstones. The Lower Keuper Sandstone or Waterstones seem to have passed into a marly facies, and not improbably some of the beds referred to as Keuper Sandstones in the borings are of Bunter age (9). On this view the Trias in the Lincolnshire borings will be divided as shown in the preceding Table, and may be regarded as consisting of about 900 to 1,000 ft. of Keuper and 800 ft. or more of Bunter.

Permian.

The Permian Limestones and Marls were passed through at Haxey and proved to be 545 ft. thick (7).

MIDDLESEX AND HERTFORDSHIRE.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Alluvium and Valley Gravel	—
	Glacial Drift and Plateau Gravel ...	—
Eocene ...	Bagshot Beds	to 80
	London Clay (proved to 353 ft.)	probably 400–450
	Reading Beds, 31 ft. to 98 ft. ...	31–107
	Thanet Sand, distinguishable in borings only, 0 ft. to 55 ft.	
Cretaceous	Upper Chalk	190–275
	Middle Chalk	200–267
	Lower Chalk	170–208
	Upper Greensand, Gault ... ... Selbornian ...	up to 44, 215

Proved in borings only :—

Jurassic	to 64
Palæozoic	—

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South of a line from Watford to Hatfield and thence to Ware the surface is occupied mainly either by Eocene or Superficial deposits; north of this line it is formed of Chalk, with Eocene outliers here and there, except where, on the northern border of Hertfordshire, small areas of Gault are included within the county boundary.

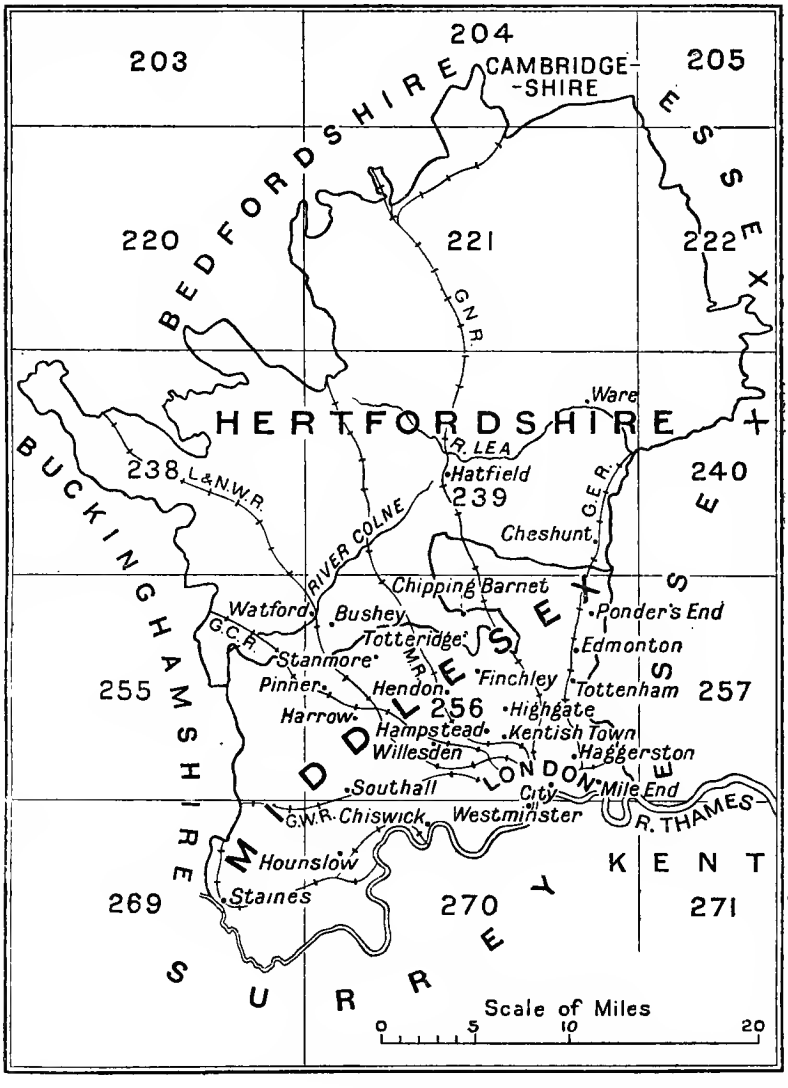
SUPERFICIAL.

Recent Alluvium occupies considerable areas in the valleys of the Lea and the Colne. Older river-deposits cover a much larger space west of the Lea, in the valley of the Thames, between the outfall of the Lea and that of the Colne, and including the area now occupied by London. Thus we find at Chiswick, Valley Drift (sand and gravel), 40 ft.; at Hatton (west of Hounslow), River Gravel, 14 ft.; at Haggerston, Valley Drift (sand and gravel), 7 ft. (2). Glacial Drift also varies greatly in thickness. Thus, at Finchley (North End) there was 42 ft. of Boulder Clay above 13 ft. of sand and gravel of Glacial age. At Finchley Common,

25 ft. of Boulder Clay and then London Clay (2). The Boulder Clay of this district is a tough clay containing many fragments and pebbles of chalk and of flint, with occasional beds of sand and gravel. Plateau Gravel, sometimes called Pebble Gravel, and consisting of pebbles of flint and quartz, with a certain amount of loam or clay, overspreads some of the higher ground. It may be seen at Pinner, Stanmore, Totteridge, Chipping Barnet, and other places (6), but is of no great thickness.

The material on the dip-slopes of the Chalk in Hertfordshire and elsewhere, which is known by the general name of Clay-with-flints, varies indefinitely in thickness and in character.

FIG. 19. MIDDLESEX AND HERTFORDSHIRE.



Eocene.

Bagshot.

The Bagshot Beds occur as outliers at Harrow, Hampstead, and Highgate Hills. At Hampstead there may be a thickness of about 60 or 80 ft. of this formation which has survived denudation (1). It consists mainly of fine sand with thin layers of clay, and the lower part is generally loamy.

London Clay.

London Clay is seldom at its full thickness except where the Bagshot Beds overlie it. At Hampstead, in a borehole, a thickness of 353 ft. was traversed, but the boring started upwards of 50 ft. below the top of the formation. Between Hampstead and the Thames, where a part only of the formation is present, the thickness met with is occasionally less than 100 ft. (2).

Reading Beds and Thanet Sand.

The Reading Beds occupy but a small proportion of the surface, but have been traversed in a large number of wells. Their delimitation from the Thanet Sands is always difficult, and in well-sections often impossible. The two are therefore grouped together in the Table on p. 92. The Reading Beds consist generally of red and mottled clays of various colours irregularly bedded with loams, sands and a more or less persistent pebble-bed. The Thanet Sand is usually glauconitic.

In Hertfordshire the Thanet Sand is rarely, if ever, recognisable, and the thickness of Reading Beds varies from 31½ to 68 ft. In Middlesex the united thicknesses of Reading Beds and Thanet Sand vary from a minimum of 27½ ft. (Pinner) to a maximum of 107 ft. (East London) in an eastward direction, and from a minimum of 56 ft. (Hendon) to a maximum of 103 ft. (Westminster) in a southward direction, but the changes in thickness indicated by these figures proceed with much irregularity.

Aggregate Thickness of Reading Beds and Thanet Sand in Middlesex.

	Feet.
East Middlesex:—Ponder's End and Edmonton southwards to Tottenham and London City ...	62–107
Central Middlesex:—Hendon and Finchley southwards to Hampstead and Westminster	56–103
West Middlesex:—Pinner and Harrow southwards to Southall and Staines	27½–80

In East and Central Middlesex about 30 to 40 ft. of the thicknesses given above are assigned to the Thanet Sand, but in West Middlesex the amount so assignable is greatly reduced, and the subdivision disappears before it reaches the outcrop.

Cretaceous.

The thicknesses of the Chalk, Upper Greensand and Gault have been determined in the deep borings enumerated in the Table on p. 96.

Chalk.

The Upper Chalk includes at its base the Chalk Rock, which consists of bands of hard nodular limestone of a yellowish tint, but showing a green coating on many of the nodules. The bands are interbedded with soft chalk, and the whole attains a thickness of about 15 ft. A specimen assignable to the Chalk Rock was obtained from a depth of 161 to 169 ft. in the boring at Bushey, and it is estimated that the total thickness of Upper Chalk in that neighbourhood must be about 190 ft. (5). At Kentish Town and Mile End 244½ and 259 ft. respectively were assigned to the Upper Chalk. Further south the thickness increases to upwards of 400 ft. (p. 73).

The Middle Chalk includes at its base the Melbourn Rock, a hard nodular yellowish chalk about 9 ft. thick. An average thickness of 220 ft. is assigned to this subdivision in Hertfordshire (4). At Bushey it appears to have been about 267 ft. (2) and at Mile End 200 ft. (2).

The Lower Chalk contains at about 100 ft. from its top the Totternhoe Stone, a hard stony chalk about 20 ft. thick, sometimes occurring in two bands with marly chalk between, and containing green-coated nodules. Below this the Lower Chalk includes a variable thickness of Chalk Marl. The total thickness of the Lower Chalk varies from 170 ft. to 200 ft. in Middlesex and Hertfordshire (1 and 4). At Cheshunt 184 ft. were assigned to it, and at Bushey 255 ft.?, of which 119 ft. were supposed to consist of Chalk Marl. At Tottenham Court Road the thickness was 208½ ft., including 32 ft. of Chalk Marl. At Mile End the thickness was 195 ft. (2).

Upper Greensand and Gault.

The Upper Greensand is the lithological name for so much of the upper part of the Selbornian as can be described as a sand or sandstone. That part varies in thickness from 12 to nearly 44 ft. in the counties under consideration. The Gault, which is the name applied to the remaining portion of the Selbornian and which characteristically denotes a clay, varies from 130 to more than 200 ft. in thickness. The united thickness of the Upper Greensand and Gault varies from 138 ft. (Southall) to 252 ft. (Willesden) as reported, but it is almost certain that the base of the Chalk was not correctly determined at Willesden. Much of the so-called Gault is Chalk Marl.

Jurassic.

The Jurassic rocks have been proved at Tottenham Court Road only. They consisted in the main of limestone attributable to the Great Oolite. Their distribution in Middlesex and Hertfordshire is unknown, except so far that they were absent in the other borings mentioned, but were present in parts of Surrey (Richmond and Streatham, p. 135).

PRINCIPAL BORINGS IN MIDDLESEX AND HERTS.

(Thicknesses in feet.)

	Ware, Herts. (*Quart. Journ. Geol. Soc.*, vol 1, 1894, p. 506).	Cheshunt, Herts. (*ib.*)	Bushey, Herts (2).	Southall, Middlesex (7).	Willesden, White Heather Laundry, Middlesex (7).	Willesden, Park Royal, Middlesex (7).	Chiswick, Middlesex (7).	Tottenham Court Road, Middlesex (2).	Kentish Town, Middlesex (2).	Mile End, Middlesex (2).
Woolwich and Reading Beds ...	—	36	—	71	60	97	78	51½	61½	41
Thanet Sand	—	10½	—					21	27	55
Chalk	573 (part)	680	710[1]	702	490	575	655	655½	645	654
Upper Greensand	40	44	—	138	252[2]	218[2]	177½	28	13¾	to 20
Gault	166½	153½	to 9					160	130	
Jurassic Rocks	—	—		—	—	—	—	64	—	
Palæozoic Rocks	to 35	to 29½		to 57	to 405	to 27½	to 124½	to 80	to 188½	

[1] The boring started about 28 feet below the top of the Chalk and traversed 682 feet of Chalk.
[2] Some Chalk Marl appears to have been included in the Gault.

NORFOLK.

Table of Strata exposed and proved in borings.

		Thickness in Feet.
Superficial	Alluvium	up to 120
	Glacial	up to 300
Pliocene ...	Forest-bed Series	up to 30
	Crag	up to 208
Eocene ...	London Clay	310
	Reading Beds	46
Cretaceous	Upper Chalk	1,150
	Middle Chalk	100–200
	Lower Chalk	56–125
	Gault and Red Chalk	4–60
	Lower Greensand	93–170
	Proved in borings only :—	
Jurassic ...	Clays	to 630

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SUPERFICIAL.

Alluvium.

The chief alluvial deposits of Norfolk are found in the Fen Country in the west, and in the district of the Broads in the east.

The Fen alluvium consists of peat, silt and gravel, and varies in thickness from about 30 to 50 ft. (1).

The average thickness of the alluvium in the Broads is probably about 20 ft., but at Potter Heigham it reaches 58 ft., while at Great Yarmouth a thickness of 120 ft. of "Recent Estuarine deposits" is recorded below 30 ft. of shingle and sand (6).

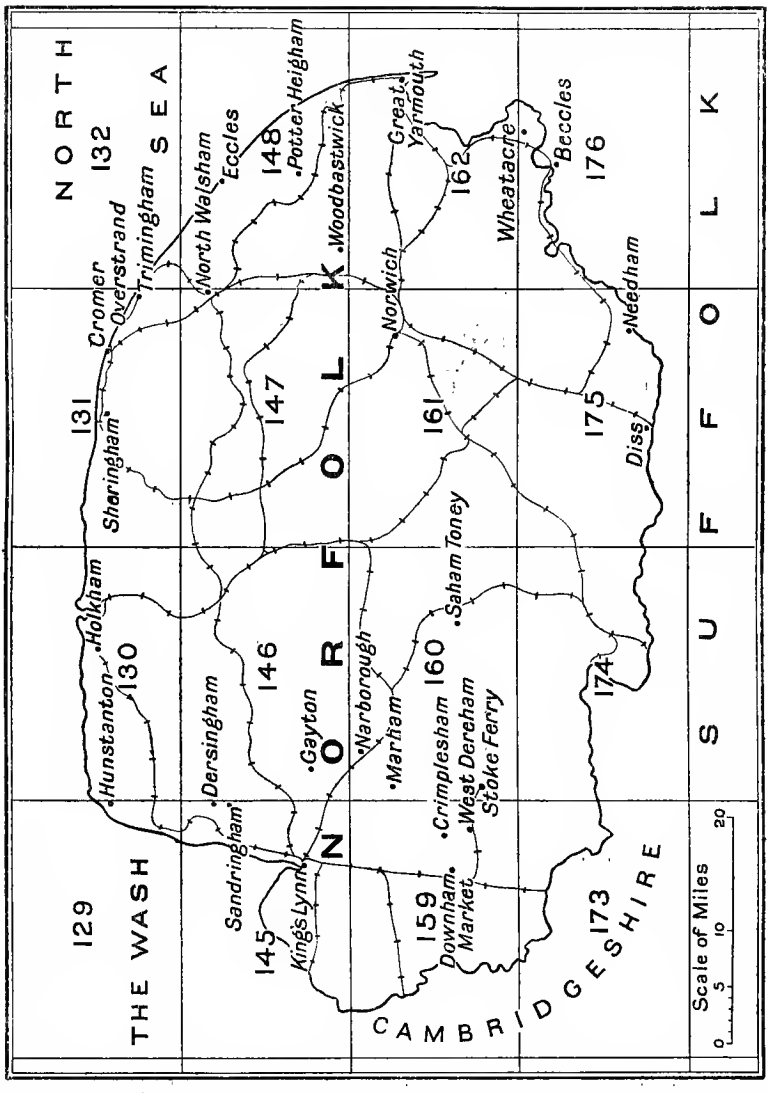

FIG. 20. NORFOLK.

Glacial.

The glacial clays, sands and gravels cover large areas in the central, northern and south-eastern parts of Norfolk. They generally extend to a depth of 100 ft., and in the Cromer district these deposits, in the form of contorted drift, have a development of 200 to 300 ft. (14).

The rock-surface on which the glacial drift rests lies below the level of the sea in many parts of the Fen Country, and also in a coastal strip extending from near Cromer to Yarmouth and along the southern boundary of the county as far west as Diss. At Yarmouth its depth below the sea is no less than 150 ft. (6). The parts of Norfolk in which the rock-surface lies at more than 30 ft.

and at more than 100 ft. below sea-level are shown on the map forming Fig. 21.

Channels in the Chalk which have been filled up with glacial material are not uncommon in East Anglia, but one only has so far been encountered in Norfolk. At Saham Toney a boring proved that superficial deposits extend to more than 100 ft. below sea-level (15).

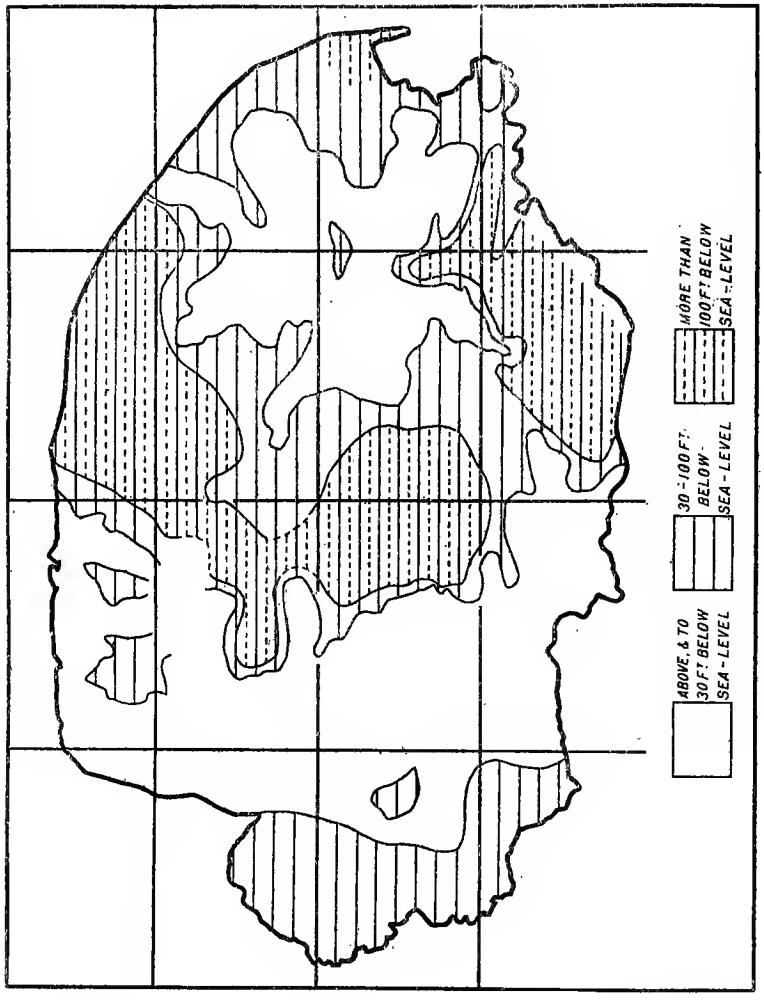

FIG. 21. MAP OF NORFOLK, showing contours in the rock-surface below sea-level.

PLIOCENE.

The Forest Bed Series occurs on the coast from Sheringham eastwards to beyond Trimingham. It is on the average about 15 ft. thick, but near Overstrand reaches 24 ft. At Trimingham the Forest Bed and Weybourn Crag have a total thickness of 40 ft. (3, 7).

The Crag occurs in East Norfolk but is generally covered by glacial deposits. At Norwich and in the Bure Valley it averages

30 ft. (7), but it thickens rapidly southwards, being 208 ft. at Wheatacre and 129 at Beccles. In the north, near Cromer (3), it is only about 10 to 15 ft. thick.

Eocene.

Lower Eocene Beds have been found in two borings. At Great Yarmouth there is a thickness of 310 ft. of London Clay, but the upper part has been removed by erosion. The Reading Beds are 46 ft. thick in the same neighbourhood, but probably do not extend west of a line running almost due north from Beccles to Eccles (6).

Cretaceous.

Chalk.

The highest Chalk known to exist in England occurs in this county. In eastern Norfolk the total thickness of the Upper Chalk has been estimated at 1,150 ft. (13), in which are comprised the zones enumerated below (13):—

Zones of the Upper Chalk at Norwich.

	Feet.
Zone of *Ostrea lunata*	110
Zone of *Belemnitella mucronata*	250
Zones of *Actinocamax quadratus* and *Marsupites* ...	400
Zones of *Micraster coranguinum* and *M. cortestudinarium*	340
Zone of *Holaster planus*	50

The Middle Chalk is about 100 ft. thick in North Norfolk but is nearer 200 ft. in thickness on the Suffolk boundary.

'Near Stoke Ferry the total thickness of the Lower Chalk is probably about 125 ft., but this decreases rapidly northwards; at Marham it is about 90 ft., and at Hunstanton it is reduced to about 56 ft.' (12). This thinning is observable both in the Chalk Marl and *Holaster subglobosus* Zone. The Chalk Marl thins from 70 to 75 ft. to 18½ ft., while the upper zone thins from about 54 ft. to 38 ft. At Norwich the Chalk-without-flints is 102 ft. thick (12).

Gault.

'The whole of the Gault clay near Stoke and Dereham is very marly, and the upper part becomes more calcareous northward.' In this direction the beds representing the Gault clay thin rapidly. At Stoke Ferry they are 58 ft.; at Roydon, 19 ft.; at Dersingham, 7 ft., and at Hunstanton, 4 ft. At Dersingham the upper part is a red clayey marl and at Hunstanton the whole is a red earthy limestone (11).

The boring at Halkham Hall, quoted in the following table, showed 8 ft. of red marl over 10 ft. of blue clay, but at Norwich the Gault was represented by more than 38 ft. of blue clay (11). This seems to show that the different facies which the Gault Clay assumes in its passage into the red rock of Hunstanton are arranged in belts running in a north-east to south-west direction.

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PRINCIPAL BORINGS IN NORFOLK.

(Thicknesses in feet.)

	Diss.	Needham.	Wheatacre.	W. Dereham.	Crimplesham.	Downham Market.	Saham Toney.	Stoke Ferry.	Narborough.	Norwich.	Great Yarmouth.	Lynn.	Sandringham.	Dersingham.	Gayton.	Woodbastwick.	N. Walsham.	Hunstanton.	Holkham.	Sheringham.	Cromer.
Alluvium	—	—	—	—	—	—	—	25	—	12	120	20	—	—	—	—	—	—	—	—	1
Glacial	100	134	8	—	30	—	248		—	—	—	30	—	—	—	16	100	—	20	107	112
Forest Bed Series	—	61	208	—	—	—	—	—	—	—	—	—	—	—	—	85	22	—	—	30	$29\frac{1}{2}$
Crag	—			—	—	—	—	—	—	—	—	—	—	—	—		18	—	—	2	
London Clay	—	—	10	—	—	—	—	—	—	—	310	—	—	—	—	—	—	—	—	—	—
Reading Beds	—	—	to 1	—	—	—	—	—	—	—	46	—	—	—	—	—	—	—	—	—	—
Upper and Middle Chalk	430	to 112	—	—	—	—	to 40	—	—	1050	to 70	—	—	—	119	189	109	—	519	to 261	to 259
Lower Chalk	60	—	—	—	—	—	—	16	85	102	—	—	—	36		—	—	56	116	—	—
Gault	to 25	—	—	60	17	—	—	58	20	to 42	—	—	6	7	26	—	—	4	18	—	—
Lower Greensand	—	—	—	to 1	93	28	—	to 17	to 48	—	—	—	to 94	to 1	to 18	—	—	to 4	70	—	—
Kimmeridge Clay	—	—	—	—	to 102	to 187	—	—	—	—	—	to 630	—	—	—	—	—	—	?	—	—

Lower Greensand.

North of Sandringham the Lower Greensand is divided into three groups:—

	Ft.
Carstone	40
Snettisham Clay	30
Sandringham Sands	100

The Snettisham Clay is in part represented by flaggy sandstone. It thickens northwards but is not known south of Sandringham (10, 14).

Jurassic.

Jurassic clays have been penetrated under the Fen deposits at Lynn to a depth of 630 ft. Probably most of this is Kimmeridge Clay, but the lower part may be Oxfordian. At Downham Market the Kimmeridge Clay was proved to be over 187 ft. thick (9).

NORTHUMBERLAND AND DURHAM.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium...	up to 50
	Glacial	to 300
Triassic ...	Keuper Marls	to 110
	Sandstones	to 1,200
Permian ...	Magnesian Limestone	299–900
	Marl Slate	Usually 3, but up to 15.
	Yellow Sands	0–104
Carboniferous		—

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SUPERFICIAL.

Alluvium.

The largest spread of Alluvium is found in the estuary of the Tees below Stockton; it includes freshwater and marine deposits and has a maximum thickness of 50 ft. (3).

Glacial.

Glacial Beds cover most of the coastal districts where the elevation is less than 1,000 ft. They consist of a lower boulder-clay, which in places reaches 300 ft. in thickness, and an overlying series composed of sand and gravel with laminated clays (3, 4).

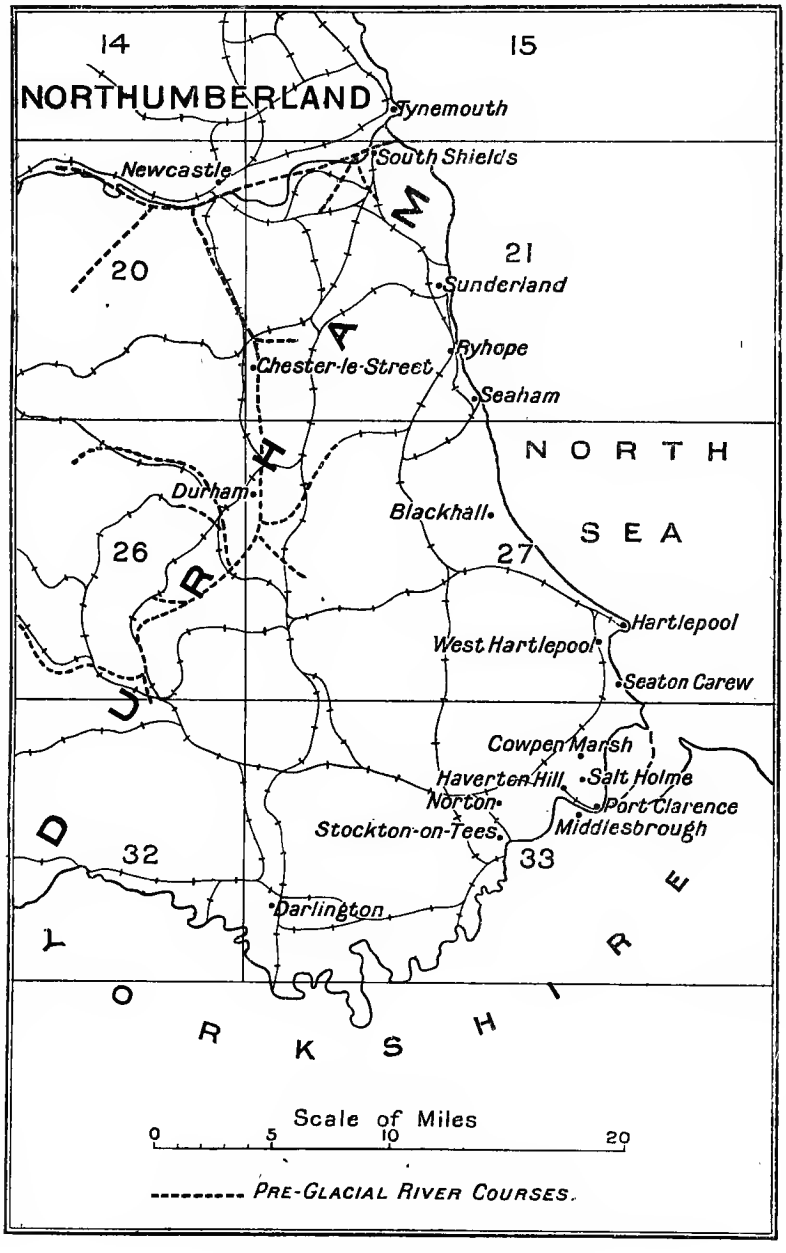
The boulder-clay is thickest where it fills buried valleys belonging to a pre-glacial river-system. The most important member of the system was the Tyne, but another buried channel follows the present course of the Wear to Durham and runs thence northwards past Chester-le-Street to near Newcastle, where it joins the Tyne buried valley at a depth of 140 ft. below present sea-level. Between Chester-le-Street and the Tyne the buried channel is known to miners as the 'Wash' (4).

TRIASSIC.

The Keuper Marl is met with only in borings and only in the south-east of Durham, where 110 ft. have been found above the Triassic Sandstones. The latter form the surface to the south-

east of a line drawn from West Hartlepool to Darlington, and reach about 1,000 ft. in thickness. Underlying the sandstones are 300 ft. of saliferous marls containing beds of gypsum, anhydrite and rock-salt, and alternating with sandstones. Where the cover of overlying strata has been sufficient to prevent solution the bed of rock-salt varies in thickness from 60 to 100 ft. (1, 3).

FIG. 22. NORTHUMBERLAND AND DURHAM.



Permian.

The Permian of Durham consists of the Magnesian Limestone, Marl Slate and Basal Yellow Sands.

The chief of these is the Magnesian Limestone, which varies from 299 to 900 ft. in thickness and may be divided into three groups: —

The upper group consists of about 100 ft. of yellow-bedded limestones; these are underlain by 250 ft. of concretionary and non-concretionary limestones and marls and 10 ft. of flexible limestone.

The middle group is 300 to 150 ft. thick and consists of brecciated limestones.

The lower group is formed by bedded brown limestones and is from 40 to 200 ft. thick (7).

The Marl Slate is a persistent 'thinly-laminated arenaceous argillaceous calcareous bed' which is usually 3 ft. thick but has a maximum development of 15 ft.

Beneath the Marl Slate there lie in places yellow sands which fill hollows in the Carboniferous floor. These sands vary in thickness from 0 to 104 ft.

In Northumberland two small outliers of Magnesian Limestone with its basal beds are found near Tynemouth.

Principal borings in DURHAM. (*Thicknesses in feet.*)

	North of Middlesbrough.	Darlington.	Norton.	Trial Bore near Saltholme.	Port Clarence.	Haverton Hill.	Saltholme.	Cowpen Marsh.	Seaton Carew.	West Hartlepool.	Blackhall Colliery.	Seaham.	Ryhope.
Alluvium and Glacial	70	166	115	77	99	105	74	87	3?	30	68	55	57
Trias — Keuper Marl	86	—	—	—	110	—	—	—	—	—	—	—	—
Trias — Sandstones	902	—	32?	846	794	497	1,175	694	256	355	—	—	—
Trias — Saliferous Marls and Sandstones	248	—		338	189	220		433	232	329	—	—	—
Permian — Magnesian Limestone ...	to 7	to 80		to 94	to 97	to 179	to 67	to —	878	to 55	657		
Permian — Marl Slate	—	—	299	—	—	—	—	—	—	—	5	499	266
Permian — Yellow Sands	—	—		—	—	—	—	—	—	—	26		
Carboniferous	—	—	to —	—	—	—	—	—	to —	—	to —	to —	to —

NOTTINGHAMSHIRE.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium	up to 33
	Glacial deposits	up to 100
	Lower Lias	up to 150
Triassic ...	Rhaetic	30–34
	Keuper Marl and Waterstones ...	740–770
	Bunter Pebble Beds and Lower Mottled Sandstone	200–680
Permian ...	Permian Marl	0–118
	Upper Limestone	0–84
	Middle Marl	0–153
	Lower Magnesian Limestone	0–273
	Marl Slate and Breccia...	0–180
Carboniferous		—

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SUPERFICIAL.

Alluvium and River Gravel.

The river-gravels and alluvium cover some 170 square miles in the county. The Trent valley is floored with about 15 to 25 ft. of gravel which is in places overlain by some silty loam or clay (7). The river-deposits as a whole range up to 32 or 33 ft. in thickness (3).

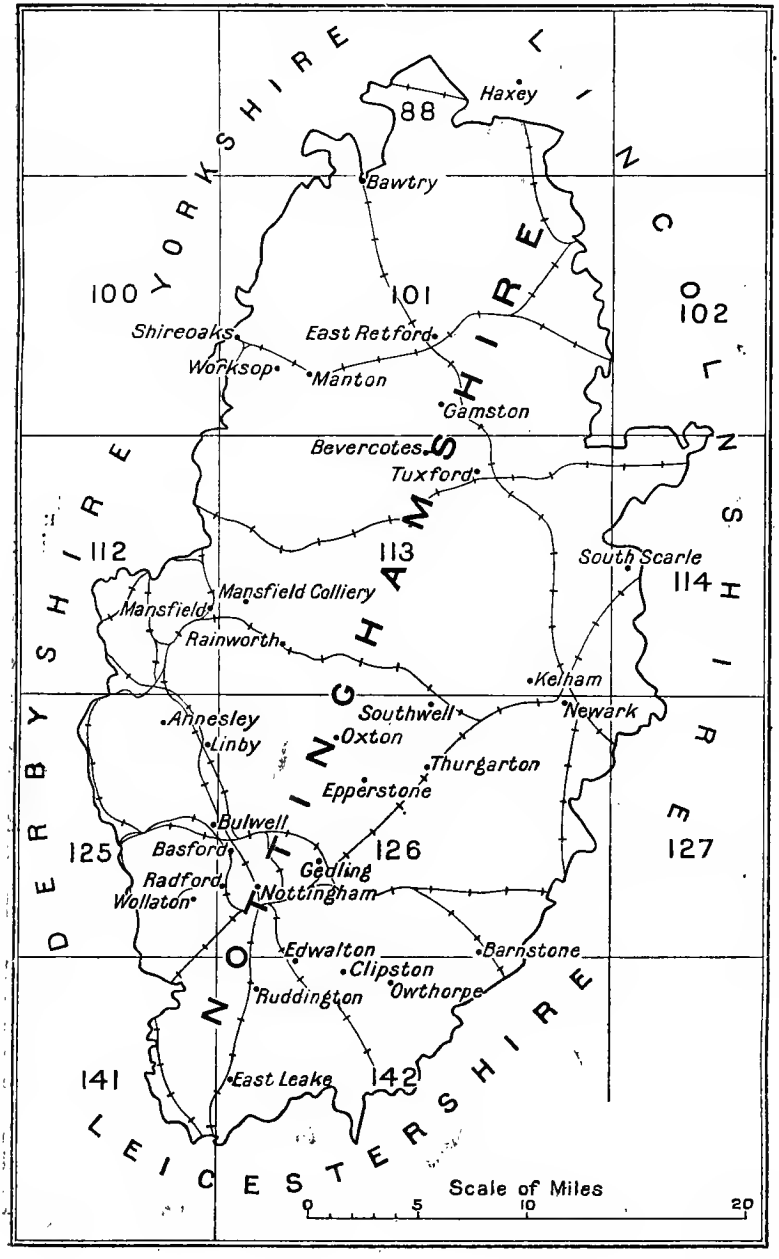
Glacial.

Glacial Drift is represented by isolated patches of sand and gravel sometimes associated with boulder-clay. By far the largest continuous tract lies south of the Trent on the Leicestershire border between the Vale of Belvoir and the Soar valley, and forms a spur projecting northward from the main mass of chalky boulder-clay of Leicestershire. In places the drift attains a thickness of 80 to 100 ft., composed occasionally wholly of boulder-clay but more often including small lenticles of sand and gravel (7).

Liassic.

The lowest subdivision only of the Lias is represented in the county. In the neighbouring parts of Lincolnshire the Lower Lias shales have an approximate thickness of 650 ft., and consist mainly of impervious clays and shales, but the Nottinghamshire border includes less than half the breadth of the outcrop (7).

Fig. 23. Nottinghamshire.



Triassic.

The complete Triassic sequence has been met with in the Owthorpe and South Scarle borings only. At Owthorpe it attains a thickness of 1,057 ft., and at South Scarle of 1,450 ft., the difference indicating a northerly increase of 394 ft. in 21 miles (6). The Bunter shows a more rapid increase than the Keuper, but the Rhaetic appears to be fairly uniform in thickness throughout the county.

The Trias of Nottinghamshire includes representations of the following subdivisions:—

Rhaetic.
Keuper { Marls. / Waterstones.
Bunter { Pebble Beds. / Lower Mottled Sandstone.

Rhaetic.

The Rhaetic Beds consist of light-coloured marls with limestones in the upper part (White Lias) and of black shales in the lower part. They make a fairly prominent escarpment in the south-west of the county. At East Leake a railway-cutting through the Normanton Hills showed about 20 ft. of the dark shales, overlain by grey shale with thin limestones which passed up into the Lias, but of which about 12 ft. was assigned to the Rhaetic (4).

At Stanton-on-the-Wolds 13 ft. of the black shales are seen, and at Owthorpe where the Rhaetic is fully developed the black shales are 14 ft. thick and the White Lias 20½ ft (4). The same thicknesses approximately are maintained northwards.

Keuper.

The north-eastward expansion of the Keuper is proved in the borings of which abstracts are given on the table following p. 110. The thickness of 893½ ft. at South Scarle appears to be an overestimate due to the difficulty of distinguishing Keuper from Bunter. The thickness assigned to the Bunter is correspondingly too small.

The Waterstones average about 100 ft. in the southern part of the county, but increase to 150 ft. at Thurgarton (3), 174 ft. at Kelham (7), and 289 ft. at Newark (3).

Bunter.

The Pebble Beds are rather coarse red sands with scattered pebbles of quartzite and other rocks. Northwards both the size and number of the pebbles decrease and at the same time bands of marl and loamy sands make their appearance, till the Pebble Beds cease to be distinguishable from the Lower Mottled Sandstone (6). The northward expansion of the Bunter is illustrated by the borings quoted later. The record of only 437 ft. in the South Carr or Haxey boring (7) may be an under-estimate as explained above. That the expansion continues into the extreme north-eastern part of the county is shown by the record of 856½ ft. at Thorne in South Yorkshire, just over the county-boundary (6).

Permian.

The Permian succession is as follows:—

Upper Permian Marl.
Upper Limestone.
Middle Marls.
Lower Limestone.
Basement Beds, Marl Slate and Breccia.

All these divisions diminish in thickness southwards and disappear two miles north of the Trent Valley. Eastwards they thicken as proved in various borings. The Upper Permian Marls are nowhere exposed in the south of the county and first appear in the Bevercotes boring as a band of variegated marl 3 ft. 2 ins. thick (6). From thence they thicken in a north-easterly direction like the other subdivisions of the Permian and Trias.

The Upper Limestone, which cannot be recognised further south than Mansfield, thickens in a north-easterly direction at a uniform rate as shown in the Table following p. 110.

The Middle Marls consist of red clays and marls with intercalations of red sandstone. At Cinderhill they show a thickness of 25 to 30 ft. (2), and north of Mansfield of 30 to 40 ft. At the latter place they are first overlain by the Upper Limestone. From the Table referred to it appears that the measurement of 153 ft. obtained at Bevercotes represents the maximum of the Middle Marls in the county (7).

The Lower Limestone commences at Radford as a coarse brecciated dolomitic rock followed by a grit (2). In the southern part of the county it is about 30 ft. thick, but it expands suddenly a mile south of Mansfield and exceeds 300 ft. in South Yorkshire.

The Basement Beds have at their base a breccia which crops out in the southern part of the county and is shown by borings to be persistent. It is seldom more than 3 ft. thick, but reaches 12 ft. near Mansfield (2). In the borings at Shireoaks and Haxey in the northern part of the county no breccia has been observed (7).

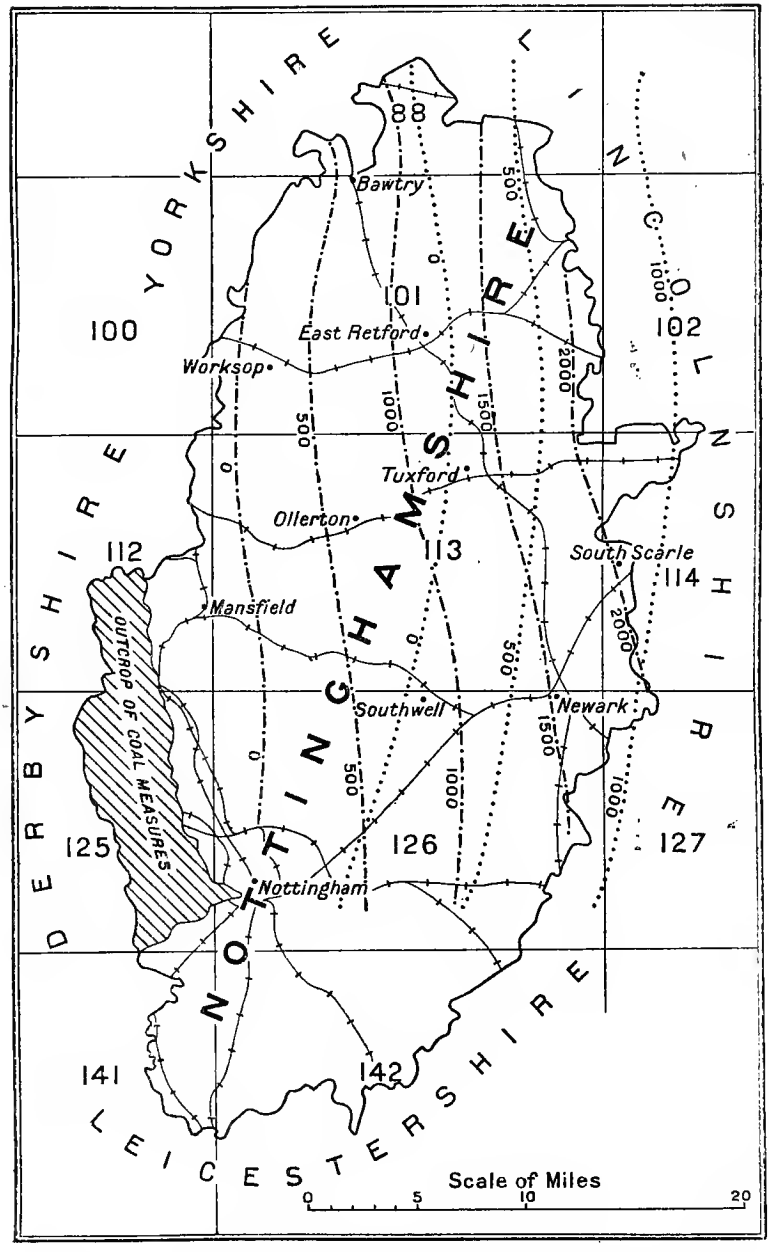
Above this comes the 'marl-slate,' consisting of sandstones and shales. In the south it is represented by 13 to 24 ft. of yellow and red marly beds, but it expands rapidly north-eastwards (7).

The map forming Fig. 24 shows, firstly, contour-lines at intervals of 500 ft. in the base of the Keuper (that is the top of the Bunter), from sea-level down to 1,000 ft. below sea-level; and secondly, similar contour-lines in the base of the Permian (that is the surface of the Coal Measures) down to a depth of 2,000 ft. below sea-level.

From it the depth to the Bunter and the depth to the base of the Permian may be calculated at any point provided that the elevation of the surface is known. It shows also the angle of dip and the direction of strike in the Bunter and Permian.

South of Nottingham several large faults affect both formations but there is no reason to suppose the existence of any important post-Permian faults between Nottingham and the Yorkshire border.

FIG. 24. MAP OF NOTTINGHAMSHIRE, showing contours in the base of the Permian and in the base of the Keuper.



.—.—.— 500 indicates a contour-line 500 ft. below sea-level in the base of the Permian (or top of the Coal Measures).

..... 500 indicates a contour-line 500 ft. below sea-level in the base of the Keuper (or top of the Bunter).

To face page 110.

PRINCIPAL BORINGS AND SINKINGS IN NOTTINGHAMSHIRE.

(Thicknesses in feet and inches. The sign + indicates that the base was not reached.)

1 in. Ordnance Map (N.S.).	142.				126.							125.		114.	113.			101.	88.
	Ruddington.	Owthorpe.	Clipston.	Edwalton.	Wilford, near Nottingham.	Basford.	Gedling.	Thurgarton.	Epperstone.	Kelham.	Oxton.	Linby.	Annesley.	South Scarle.	Rainworth.	Mansfield.	Bevercotes.	Gamston.	Manton.	Haxey.
Alluvium and Soil, &c.	1	—	11	9	21	—	7·3	21	10·6	—	3	·6	—	21	1	·10	9·9	8·0	1·2	32
Glacial	6	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
Lower Lias	—	12·6	—	—	—	—	—	—	—	—	—	—	—	29	—	—	—	—	—	—
Triassic—																				
Rhaetic	—	34·6	—	—	—	—	—	—	—	—	—	—	—	15	—	—	—	—	—	—
Keuper Marl	386	627	509	389	192	—	—	92·9	—	397·6	—	—	—	688	—	—	—	—	—	105·7
Keuper Waterstones	73·9	121·6	192	50·8		—	69	150	59·6	174	—	—	—	205·6	—	—	27·9	92·8	—	
Bunter Pebble Beds	220·7	274	258	254·4	246	—	385·2	493·5	326	671	374·6	—	—	318·6	179·9	171·4	567·9	561·4	213·4	1042·11
Lower Mottled Sandstone ...	absent	absent				18			117·3+			—	62·6	223	96	111·8	114·1	107		
Permian—																				
Upper Marls						absent	absent	absent	—	absent	absent	—	absent	118·6	absent	absent	3·2	67·6	20	58
Upper Limestone						absent	absent	absent	—	absent	absent	—	absent	43·6	absent	absent	25·6	19·8	22·6	84
Middle Marls		Absent south of the Trent.				absent	46·1	68·10	—	35	9·2	3·9	26·9	150	15·2	14·2	153·4	23·04+	68·8	132·9
Lower Limestone						29·5			—	82·6	44·4	33·4	104·1	88	14·3	68·6	202·3	—	260·6	273
Marl Slates						13		24	—	21·3	85·6	46·5		118	—	98·7	26·6	—	35·10	9 (?)
Basement Breccia or Sands ...						·9	·8	·6	—	1	2·6	1·8	·8	1	—	2·11	6	—	nil	nil
Carboniferous	1183 +	963 +	1135 +	796 +	39 +	341·6 +	875·10 +	1387 +	—	960 +	1434 +	1285·4 +	1300 +	12 +	—	1224 +	Coal Measures.	—	1314 +	1448·7 +

SHROPSHIRE.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium	up to 40
	River Gravel	up to about 20
	Glacial Drift	up to 210
Liassic	Middle Lias	30
	Lower Lias	over 400
Triassic	Rhaetic	up to 24
	Keuper Marl	up to 3,000
	Keuper Sandstone including Waterstones	450
	Upper Mottled Sandstone	500
	Bunter Pebble Beds	600
	Lower Mottled Sandstone	80–650
Carboniferous (?), ' Permian of Salopian type '		—

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SUPERFICIAL.

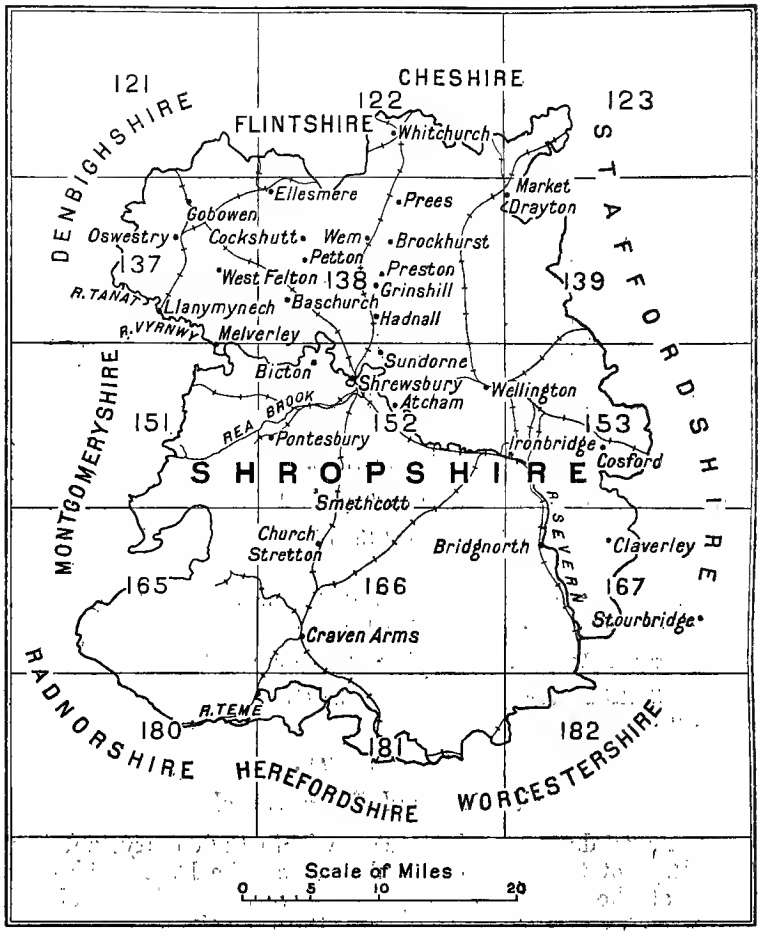
Alluvium and River Gravels.

Broad spreads of alluvium occur within the county, notably in the valleys of the Severn, the Teme, and the Rea. At the confluence of the Tanat, Vyrnwy and Severn alluvium and river-gravel occupy a wide expanse and attain a thickness that can be hardly less than 30 to 40 ft.

Glacial.

The glacial deposits occur principally in two areas, one including almost all the part of the county lying north of Shrewsbury and west of Market Drayton, and the other keeping to the eastern borders of the county south of Shrewsbury. In the former area a shaft $1\frac{1}{4}$ miles north-west of Gobowen showed a thickness of 170 ft. of boulder-clay with sand and gravel, while the Daywell Colliery close by was sunk through 180 ft. of drift. Near Oswestry the thickness is 32 ft. in the town; 35 ft. at Messrs. Ireland and Co.'s Colliery; 85 ft. at the Crosswilling shaft-sinking; 85 ft. at Dryll Colliery, one mile south of Oswestry; 125 ft. at Pen-y-lan shaft in the immediate vicinity, and 80 ft. at Trefonen, $2\frac{1}{2}$ miles south-west of Oswestry. Farther east it is further reduced, three wells at West Felton showing 12, 20 and 30 ft. respectively of glacial sand and gravel. The glacial sands

FIG. 251.—SHROPSHIRE.



are at least 30 ft. thick in the neighbourhood of Twyford, 3 miles south-east of Oswestry. North of Ellesmere they are 150 ft. thick, and about 70 ft. between Ellesmere and Cockshutt. At Petton, 5 miles west of Wem, 120 ft. of glacial gravel is recorded (5).

On the northern margin of the county 96 ft. of sand has been proved at Whitchurch and 100 ft. of drift west of Market Drayton. The same thicknesses occur around Prees and Wem, but at Preston Brockhurst, 3 miles south-east of Wem, the drift is only 10 ft. thick (3, 5).

In the neighbourhood of Shrewsbury the thickness of the glacial beds varies up to more than 100 ft. At Dunn's Heath, three miles north of the town it exceeds that amount (5), but to the immediate east, at Sundorne, falls to 34 ft. (3). Two wells in the town itself show thicknesses of 34 and 83 ft. of drift, while the Grammar School well apparently commenced in solid rock (3). To the west of the town at Bicton there is a thickness of 38 ft. of glacial gravel and clay, while at Atcham, 4 miles to the south-east of Shrewsbury, the drift is as much as 210 ft. thick (3).

In the second area, to the south-east of Shrewsbury, the drift is more irregularly distributed, though in places thicknesses of over 200 ft. are recorded. A well at Wellington traversed 45 ft. of drift (3); while at Ironbridge a thickness of more than 200 ft. is attained. The drift is also widely spread around Claverley, east of Bridgnorth, but in the south-west of the county it occurs only in scattered patches. At Hanwood, near Pontesbury, it is at least 50 ft. thick, while farther south a well near Craven Arms railway-station was sunk 46 ft. in glacial gravel. In the branch-valleys of the Smethcott Brook the glacial drift is stated to have a thickness of more than 50 ft.[1]

Liassic.

The Middle and Lower Lias form an outlier around Prees. The sandy marlstone of the Middle Lias is 8 to 10 ft. thick at Prees and below it are sandy beds passing down into more argillaceous strata which have been pierced to a depth of 20 ft. The total thickness of the Middle Lias is estimated at about 30 ft.

At Woolliston, 2 miles north-east of Prees, shafts sunk in search of coal have pierced the Lower Lias to a depth of 400 ft. without reaching the base (4).

Triassic.

Rhaetic.

The Rhaetic beds are not visible in the outlier of Prees, but just across the Cheshire county-boundary, at Audlem, 24 ft. of black shales with marls overlie the uppermost green marls of the Keuper and are overlain by glacial drift (5).

Keuper.

There are no boring-records available for the total thickness of the Keuper in Shropshire. A boring recently made at Haughton, near Baschurch, revealed a thickness of 323 ft. of Keuper Marl, but it probably began low down in the marl.

'Taking all things into account 3,000 ft. is the least thickness of the Keuper Marl which would be found if these beds were penetrated below the Lias of Prees. And if we add 450 ft. for the thickness of the Lower Keuper Sandstone, the thickness of the Keuper Beds in Shropshire is 3,450 ft.' (2).

The Lower Keuper Sandstone near Stourbridge across the south-eastern border of the county is 400 to 500 ft. thick (2), and in the Peckforton Hills in Cheshire 400 ft. (2).

Bunter.

The Upper Mottled Sandstone may average about 500 ft. in thickness. It has been estimated to reach more than that in Cheshire (p. 30) and not less than 215 ft. in Worcestershire (p. 138). At Grinshill it has been sunk through for more than 222 ft. (1). A boring at Cosford (p. 124) traversed a large part of the Bunter.

The Pebble Beds have been estimated at 600 ft., but no definite line can be drawn either at their top or their base.

The Lower Mottled Sandstone varies from 80 ft. south-east of Market Drayton to upwards of 650 ft. near Bridgnorth (2).

[1] Lapworth and Watts 'Geology in the Field.' *Geol. Assoc.*, 1910, p. 764.

SOMERSET.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium...	to 85
Cretaceous ..	Middle Chalk	150
	Lower Chalk	200
	Upper Greensand	100–180
	Gault	to 90
Oolitic ...	Corallian	120
	Oxford Clay with Kellaways Beds ...	400
	Cornbrash	20–25
	Forest Marble (with Bradford Clay) ...	90–130
	Great Oolite	0–110
	Fuller's Earth	35–420
	Inferior Oolite	7–118
	Midford Sands	0–200
Liassic ...	Upper Lias	10–50
	Middle Lias	to 230
	Lower Lias	to 500
Triassic and Permian.	Rhaetic	20–75
	Keuper Marl	to 1,350
	Upper Sandstones	to 300
	Pebble Beds	to 100
	Lower Marls	to 200
	Lower Sandstones	to 500
Carboniferous and older rocks	... ...	—

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SUPERFICIAL.

Alluvium.

Broad plains of estuarine and fluviatile alluvium lie around Bridgwater and between Glastonbury and the Bristol Channel.

Smaller areas occur to the east of Weston-super-Mare. At this locality a boring showed 76½ ft. of alluvium on Keuper Marl.

Peat has been dug to a depth of 15 ft. on the low ground to the west of Glastonbury.

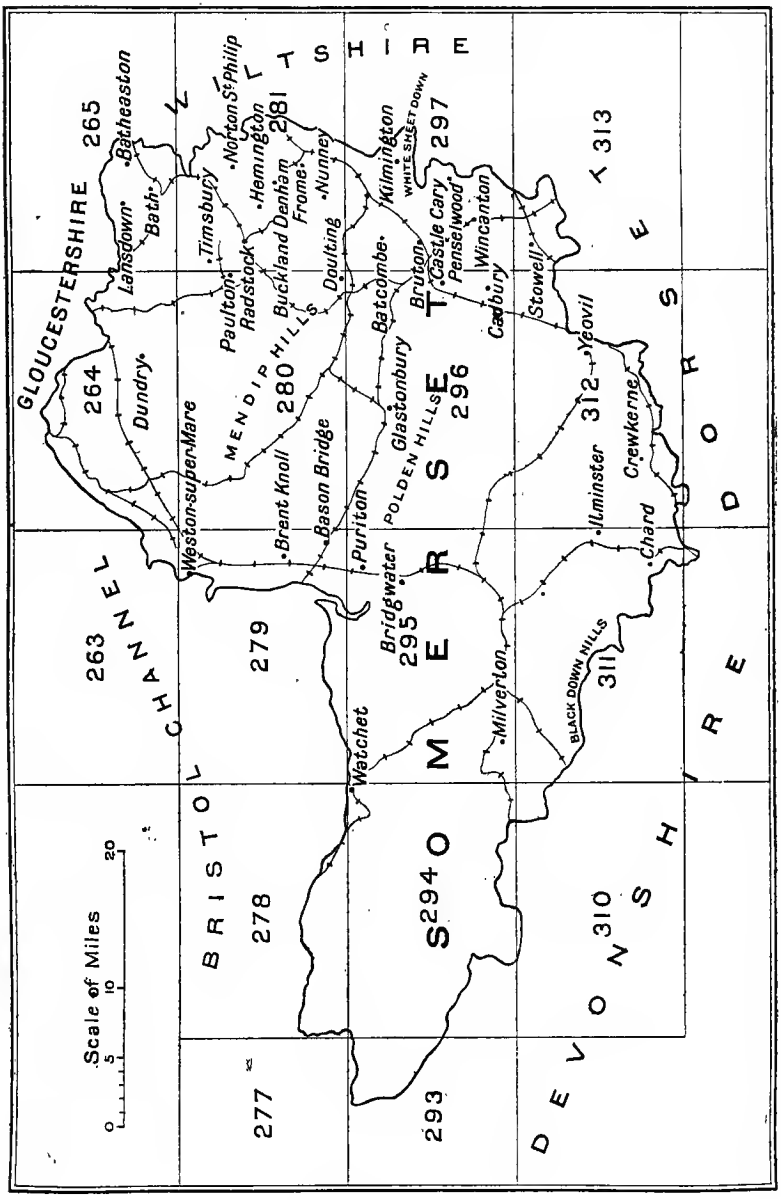

FIG. 26. SOMERSET.

CRETACEOUS.

Chalk.

'Near Crewkerne the Lower Chalk . . . is about 90 ft. thick. At Chard it is thinner, probably from 60 to 70 ft., consisting of (i.) the basal nodule-bed, which is a fairly hard rock full of fossils and phosphatic nodules; above is (ii.) glauconitic chalk passing up into white chalk, and finally (iii.) grey and buff marls.' Nodular rock like Melbourn Rock occurs near Crewkerne.

The basal nodule-bed has been generally regarded as representing the Chloritic Marl, and is taken by Mr. Jukes-Browne as a condensed representative of the lower part of the Chalk Marl (6).

Selbornian.

'South of Crewkerne the thickness of the Greensand is not much over 100 ft. . . , but as they are followed westward to Chard several parts of the formation increase in thickness, and the total amounts to about 180 ft. Thus, the Chert-beds, which near Crewkerne are only 5 to 6 ft. thick, thicken to 25 and 30 ft. near Chard; and the soft yellowish sands which form the central part of the series, and are commonly known by the name of "Foxmould," reach nearly twice the thickness they have in West Dorset.' The upper part of the Selbornian consists for a thickness of 8 ft. of a hard limestone with quartz-grains and hard calcareous grit (5). The lower part, for a thickness of 70 to 90 ft., has a clayey aspect in East Somerset, and is there distinguished as Gault. In the Blackdown Hills the Gault is not distinguishable as a clay.

OOLITIC.

The Selbornian rests unconformably upon the Jurassic and Triassic rocks and oversteps them westwards. The highest Jurassic strata visible in Somerset belong to the Corallian.

Corallian.

The thickness of the Corallian is believed to be about the same in Somerset as in North Dorset, namely, 120 ft. (4).

Oxford Clay with Kellaways Beds.

The outcrop of the Oxford Clay runs from near Wincanton to near Frome. Near Witham Friary the formation was proved in a boring to exceed 220 ft. in thickness, including upwards of 50 ft. of sand-stones, limestones and marls attributable to the Kellaways Beds. The total thickness in Somerset is likely to be about 400 ft.

Cornbrash.

The Cornbrash ranges through the county at the base of the Oxfordian. At Wincanton there is evidence of 25 ft. of earthy and sandy limestones with intercalated marly bands (3).

Forest Marble.

This subdivision consists of an upper part of 15 to 20 ft. of shelly oolitic limestones (Frome Stone) and of a lower more clayey part in which is included the Bradford Clay. False bedding in the limestones is usually conspicuous. The total thickness of the Forest Marble has been estimated at 130 ft., diminishing to 90 ft. north of Frome.

Great or Bath Oolite.

This oolitic limestone is strongly developed in the neighbourhood of Bath, and there reaches a thickness of 100 to 110 ft. Southwards it thins away, finally disappearing near Norton St. Philip, probably having been unconformably overlapped.

Fuller's Earth.

The Fuller's Earth is thickest in the southern part of the county. At Cadbury it has been estimated to be as much as 420 ft. (1). A borehole at Stowell (7) and an estimate at Bruton[1] give the following measurements:—

	Stowell Borehole.	Bruton.
Upper Fuller's Earth	120 (part)	133
Fuller's Earth Rock	35	25
Lower Fuller's Earth	177	21

Around the eastern end of the Mendip Ridge the thickness varies between 35 to 100 ft. South of Bath the full thickness has been estimated at 135 to 150 ft., but at Lansdown it appears from an old well-section to be 70 ft. (3).

Inferior Oolite and Midford Sands.

The Inferior Oolite Series is divided into the Inferior Oolite above and the Midford Sands below, but along the eastern borders of the Mendip Hills the Inferior Oolite overlaps the beds below and rests on Palæozoic rocks (3).

Near Yeovil the Inferior Oolite is 7 ft. thick and rests on the Midford Sands, but in the boring at Stowell the Inferior Oolite limestones had a thickness of 118 ft. (7). Further north, near Bruton, they are between 45 and 60 ft., at Nunney 80 ft., and at Hemington 39 ft. thick. In the Bath area the measurements give 25 to 45 ft. The maximum thickness in the outlier of Dundry Hill is stated to be 85 ft. (1).

The Midford Sands are best developed in the south of the county, where they are about 200 ft. thick. They thin northwards, being 165 ft. near Castle Cary, only 66 ft. near Bruton, and absent near Radstock.

On Brent Knoll they are 200 ft. thick, and a thickness of 174 ft. of them is preserved on Glastonbury Tor.

In the neighbourhood of Bath they vary from 40 to upwards of 100 ft., being 100 ft. thick at Lansdown and 103 ft. at Midford.

On Dundry Hill there is only 2 ft. of sands between the Inferior Oolite and the Liassic Clays.

Liassic.

The Upper Lias of Somerset consists chiefly of clay with some limestones, and varies between 10 and 50 ft. in thickness. In the south at Ilminster it is 10 ft. thick, but on Glastonbury Tor it expands to 49 ft. On Dundry Hill it is only 8 ft. thick, and in the Bath area also it is thin, but from Batheaston eastwards it seems to thicken again.

The Middle Lias consists of earthy limestones and marls, about 8 to 12 ft. thick and known as the Marlstone, in the upper part; in the lower part it is made up of sandy clays.

[1] De la Beche, *Mem. Geol. Surv.*, vol. i, 1846, p. 280.

The total thickness near Ilminster has been estimated at 160 ft. and near Glastonbury at 230 ft. But further north it thins away, for it occurs in an attenuated form only, if at all, between Batcombe and the Mendip Hills, near Doulting, and on Dundry Hill is absent (2).

The Lower Lias consists of limestones and clays in the lower parts while the higher beds are nearly all clay. It reaches its greatest thickness of 450 to 500 ft. in the south of the county at Chard. North of Ilminster and in the Polden Hills it seems to be slightly over 300 ft. thick (2). At Baston Bridge a boring proved more than 415 ft. of Lias, all of which may have been Lower Lias.

On the east of the Mendip Hills the Lias is overlapped by the Oolites, but to the north, near Radstock, it expands rapidly farther away from the Mendip Ridge, and around Paulton and Timsbury reaches a thickness of 110 to 150 ft. (2).

At Dundry the Lower Lias is about 440 ft. thick, but near Bath it is only 250 ft. To the east of Bath a boring in Wiltshire shows that it has thickened again to over 400 ft.

Triassic and Permian.

The Rhaetic is divided into the White Lias above and black shales below. In West Somerset the series is not far short of 75 ft. in thickness, but towards the Mendip Hills it becomes attenuated (8). In some places near Radstock it is only 21 ft. thick.

The only representative of the Trias in the northern part of the county is the Keuper Marl with its basal 'Dolomitic' conglomerate. It has been laid down on an undulating surface of the Palæozoic rocks, and naturally varies greatly, but seldom exceeds 200 ft. in thickness. South of the Mendip Hills, however, the whole assemblage of the newer red rocks attains a great development. The only direct evidence of their thickness is furnished by a boring at Puriton; at Milverton an estimate has been made by Mr. Ussher (9):—

	Puriton boring.	Milverton estimate.
Keuper Marl	to 1,252	1,350
Upper Sandstones	202	300
Pebble Beds	14	100
Lower Marls	to 582	200
Lower Sandstones		500

The Lower Marls and Lower Sandstones are regarded as Permian (see Devon, p. 40).

SOME BORINGS IN SOMERSET.

(Thicknesses in feet.)

	Lansdown (Bath).	Weston-super-Mare.	Baston Bridge.	Paulton.	Radstock.	Hemington.	Buckland Denham.	Puriton.	Chard.	Stowell.
Alluvium and Soil	—	76½	85	—	—	6	—	23	7	—
Chalk	—	—	—	—	—	—	—	—	104	—
Upper Greensand and Cherts	—	—	—	—	—	—	—	—	184	—
Fullers Earth	20	—	—	—	—	81	—	—	—	332
Inferior Oolite	30	—	—	—	35	39	} 160	—	—	118
Midford Sands	100	—	—	6	—	—	}	—	—	to 103
Lias	to 24	—	to 415	150	90	29	80	—	to 5	—
Rhaetic	—	—	—	—	—	42	40	—	—	—
Keuper Marl	—	to 3½	—	138	186	139	320	1252	—	—
Upper Sandstones	—	—	—	—	—	—	—	202	—	—
Pebble Beds	—	—	—	—	—	—	—	14	—	—
Lower Marls and Sandstones	—	—	—	—	—	—	—	to 582	—	—
Coal Measures	—	—	—	to	to	to	to	—	—	—

STAFFORDSHIRE.

Table of Strata.

			Thickness in feet.
Superficial		Alluvium	0–30
		River Gravel	
		Glacial Deposits	0–102
Trias ...		Rhaetic—Shales and limestones ...	?
	Keuper	Marls	700–1,000
		Sandstone (Waterstones) ...	200–400
	Bunter	Upper Mottled Sandstone	300–510
		Pebble Beds	250–380
		Lower Mottled Sandstone	0–300
Permian ...		Red and purple sandstones and marls	170–350
		Breccia	
		Sandstone and marl with calcareous conglomerate	200–325

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SUPERFICIAL.

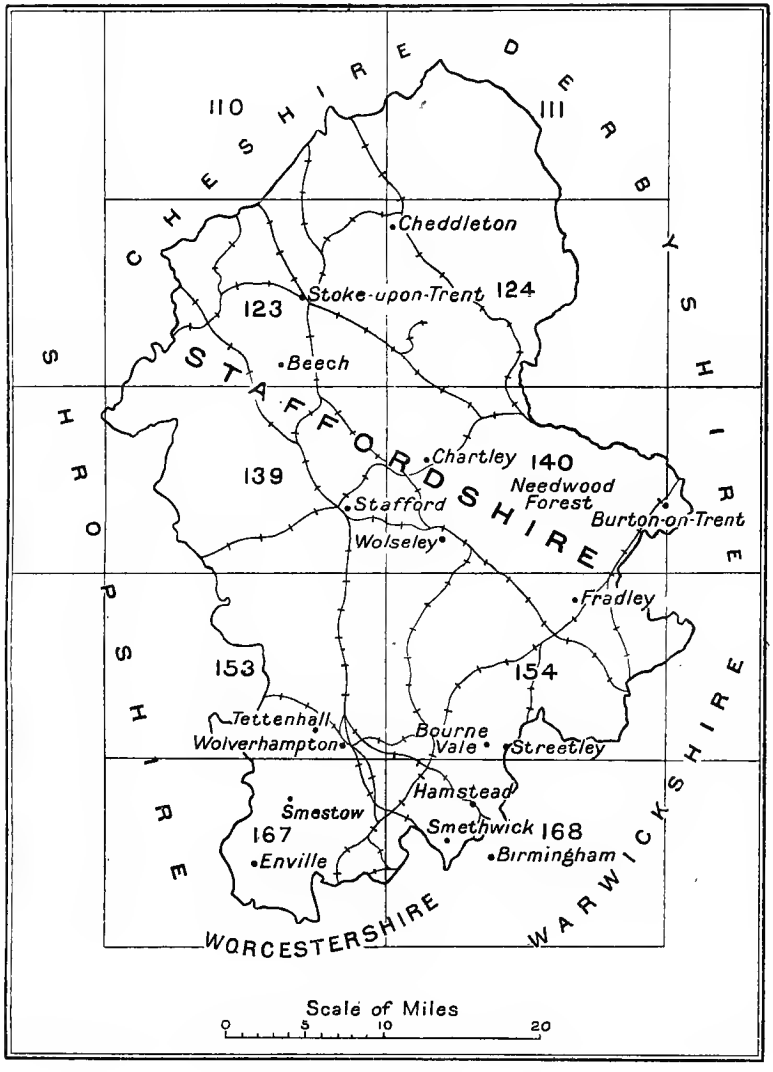
Alluvium and Valley Gravels.

Alluvium and valley-gravels occur in many of the valleys and especially in the valley of the Trent. At Burton-on-Trent the old brewery-wells were sunk in the valley-gravel and were generally not more than 20 ft. deep.[1]

The gravel reaches 30 ft. in thickness in a well on the east side of the High Street,[2] and at the London and Colonial Brewery, 40 ft. of red gravel and sand were proved resting irregularly on red marl.[3] At another Burton well 24½ ft. of old river-gravel was penetrated before the Keuper Marls were reached. At a bore at Cheddleton the alluvium was found to be 11½ ft. thick and to rest on Pebble Beds.

[1] *Rep. Brit. Assoc.* for 1875, p. 119. [2] *Ib.* p. 119. [3] *Ib.* for 1878, p. 389.

FIG. 27. STAFFORDSHIRE.



Glacial.

Boulder-clay, sands and gravels cover much of the lower ground and especially the outcrop of the Triassic rocks. They attain a thickness of over 100 ft. in places, exceptional developments being usually found in pre-glacial river-beds which have been filled up with drift. At Stoke Road, Skelton, and in the central part of the South Staffordshire coal-field examples of such buried valleys have been met with. In the northern part of that coal-field the measures are almost completely concealed by a mantle of drift ranging up to more than 50 ft. in thickness. At Smethwick borings have shown the usual variations in the

thickness of this cover; 102 ft. were passed through at the Gas-works, but at the Railway Carriage and Wagon Co.'s Works, only 34 ft. before reaching the rock.

Triassic.

Rhaetic.

A small outlier occurs in Needwood Forest.

Keuper and Bunter.

These rocks occupy a basin in the central part of the county and fringe the North and South Staffordshire coal-fields. The following table shows their thicknesses on the two sides of the latter coal-field (4, with additions from an account of the Cosford boring published in the *Brit. Assoc. Rept.* for 1887, and from an unpublished boring at Tettenhall):—

		West side. Ft.	East side. Ft.
Keuper	Marls	1,000	700
	Sandstone (Waterstone) ...	400–300	200
Bunter	Upper Mottled Sandstone	300–510	300 to 250
	Pebble Beds	300–380	
	Lower Mottled Sandstone	300–0	absent.

It will be noted that the aggregate thickness is greater on the west than on the east side.

The thickness of the Triassic rocks traversed by various borings is shown in the Table on p. 124. The total has not been proved in any one boring, but the Smestow boring started about 200 ft. below the top of the Bunter and was continued to its base. The total thickness of Bunter at that spot is about 1,250 ft.

The Upper Mottled Sandstone is not separable from the Pebble Beds around Stoke-upon-Trent, and the two together reached an aggregate of more than 600 ft. at Whitmore (7, p. 140). Other measurements are given on p. 124.

The Lower Mottled Sandstone is absent in the Stoke-upon-Trent area, and the Pebble Beds rest on the Upper Carboniferous rocks with a great unconformity. Also on the east side of the South Staffordshire coal-field the Lower Sandstone is absent, but on the west side it has been estimated to reach as much as 300 ft., though not always present. At the Cosford well near Wolverhampton it was penetrated to $78\frac{3}{4}$ ft., and at the Tettenhall well was proved to be more than 184 ft.

Permian.

The separation of the Permian from the Trias has not yet been effected everywhere with precision. In North Staffordshire part of the red rocks which intervene between the Bunter and the productive Coal Measures were formerly regarded as Permian; all are now included in the Carboniferous. In South Staffordshire, though some of the so-called Permian can be definitely assigned to the Carboniferous, there remain some strata of which

the age cannot be determined on the fossil evidence as yet available (9). These are left in the Permian system for the present. At Enville the following sequence is presented:—

		ft.
Red and purple sandstones and marls formerly called 'Upper' Permian		170–350
Trappoid breccia	(Formerly called 'Middle' Permian)	200–325
Sandstone and marl ...		
Calcareous conglomerate		
Sandstone and marl ...		
Calcareous conglomerate		

The underlying strata (formerly called 'Lower' Permian) are now classed as Carboniferous in accordance with the observations of Mr. Cantrill (3, pp. 530-533).

The thickness of the Permian group has been estimated at between 500 and 625 ft. (5, Table I, p. 108), but the Streetley boring, below the Bunter, penetrated 1,830 ft. of marls, breccias and conglomerates which are younger than the Keele Beds and believed to be of Permian age (8).

PRINCIPAL BORINGS IN STAFFORDSHIRE.

(Thicknesses in feet and inches.

	Stafford Common.	Chartley.	Wolseley.	Messrs. Worthington & Co., Burton-on-Trent.	Tettenhall.	Cosford (Shropshire).	S. Staff. Brewery Co., Wolverhampton.	Smestow Brook, Wombourne.	Fradley.	Streetley or Little Aston.	Bourne Vale.	Messrs. Allen, Everitt & Sons, Smethwick.	Gas Works, Smethwick.	Carriage & Wagon Co., Smethwick.
Superficial—														
Alluvium and River Gravel	10.6	—	—	30	—	—	—	—	—	—	—	—	—	—
Glacial...	—	19	—	—	—	—	—	—	8.6	—	55.6	33	102	34
Trias—														
Keuper—														
Marls	to 772.6	882	—	297 to 123	—	—		—	169.8 to 348	—	—	—	—	—
Sandstone and Waterstones	—	449	—		34.6	—		—		—	—	—	—	—
Bunter—														
Upper Mottled Sandstone	—	816.6	—	—	510	461.6	200 ?							
Pebble Beds ...	—		253.10	—	374 to 184	378.6 to 78.9		1050	—	125[1]	68.6	267	—	—
Lower Mottled Sandstone	—	—	—	—					—	—	—		—	—
							to 60			to 1830				
Permian	—	—	—	—	—	—		—	—		—	—	—	170
		to	to								to		to	to
Carboniferous	—	1283.6	935.9	—	—	—	—	—	—	—	127	—	198 ?	456

[1] Including Hopwas Breccia.

SUFFOLK.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Alluvium	up to 40
	Glacial Drift	up to 470
Pliocene	Forest Bed Series	11–14
	Norwich Crag	up to 166
	Red Crag	20–30
	Coralline Crag	50–60
Eocene	London Clay	up to 170
	Reading Beds	up to 70
Cretaceous	Upper Chalk	—

Proved in borings only :—

Cretaceous	Upper Chalk	up to 556
	Middle Chalk	164
	Lower Chalk	154
	Gault	50–73
	Lower Greensand	0–41
Palæozoic Rocks		—

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SUPERFICIAL.

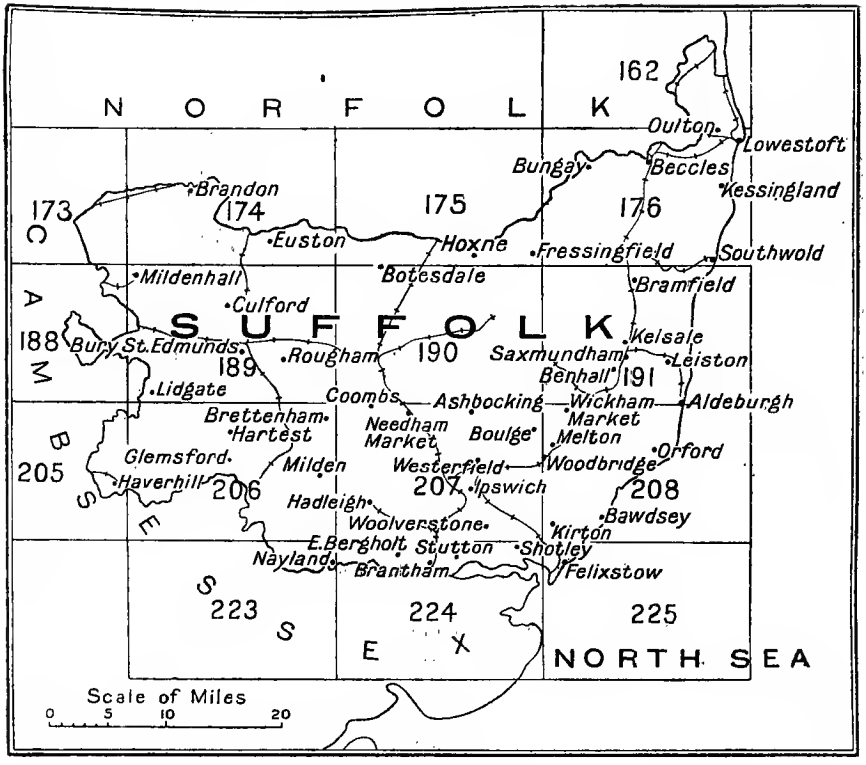
Alluvium.

The alluvial deposits occupy a narrow strip of low coastland from Aldeburgh to Felixstowe, and also occur to a small extent in the valleys of the main rivers. The thickness on the Lantern Marshes, Orford, reaches 30 ft. (6).

Glacial.

Glacial deposits cover most of the county but in two areas are absent or not more than 30 ft. thick. One of these forms a belt of low ground lying to the east of a line drawn from Lowestoft in the north to Nayland in the south-west; the other lies on the Chalk plateau to the north-west of a line drawn through Botesdale, Bury St. Edmunds to Lidgate, but is broken by a tongue of drift running north-westwards from Rougham to near Brandon. There are also two small areas in which the drift is thin, one

FIG. 28. SUFFOLK.



near Milden and the other south of Needham Market to the north-west of Ipswich.

On the other hand the drift is over 100 ft. thick in a large irregular tract, stretching from Haverhill in the west, through the central part of the county to Wickham Market in the east, except only in the two small areas of thin drift mentioned above. Another smaller area where the drift is more than 100 ft. thick stretches from Fressingfield to near Bungay.

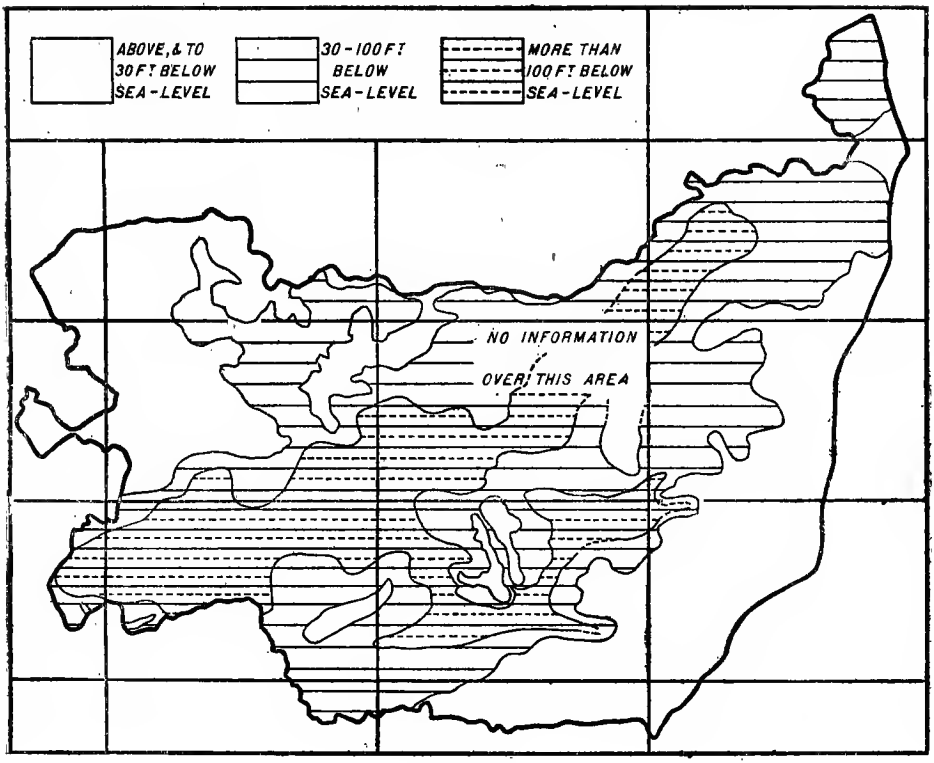
In some well-sinkings the solid rock has been proved to lie below sea-level. The most remarkable of these is the Glemsford boring, which showed a thickness of 470 ft. of drift, resting on chalk at 348 ft. below Ordnance Datum (6).

The borings show further that in Suffolk there are channels of pre-glacial or glacial origin now filled with drift.

Around Lowestoft and at several points along the coastal border the surface of the Crag is slightly below sea-level, but there is insufficient information for the tracing of any buried channels.

The parts of Suffolk in which the rock-surface lies at more than 30 ft., and more than 100 ft. below sea-level are shown on the map forming Fig. 29.

FIG. 29. MAP OF SUFFOLK, showing contours in the rock-surface below sea-level.



PLIOCENE.

The Forest Bed Series occurs in the north-eastern part of the county, where it has an average thickness of 12 ft. (6).

The Norwich Crag occupies a triangular area to the north-east of a line drawn from Hoxne to Aldeburgh. At Aldeburgh it is absent, but it thickens rapidly northwards, being possibly 60 ft. at Hoxne, 100 ft. at Saxmundham and 147 ft. at Southwold (6).

In borings the Crag is seldom divisible into its separate stages, but near its outcrop the Red Crag is estimated as having a thickness of 20 to 30 ft. (7), and the Coralline Crag of 50 to 60 ft.

The greatest thickness of Crag is recorded as 194 ft. (6), from a boring at Oulton Broad. In the south-east of the county it is greatly reduced. At Shotley it is 17 ft. and at Melton 11 ft. thick (6).

EOCENE.

Part of the London Clay exists in the east and south-east of Suffolk. Owing to the overlap of the Crag it is absent or reduced to about 10 ft. over all but a coastal strip some 12 miles broad. In this strip the London Clay thickens rapidly, being 83½ ft. at Felixstowe (6) and 160 ft. at Lowestoft (8). The beds strike north and south over East Suffolk and dip eastwards at about

1 in 420 at Saxmundham and 1 in 135 near the coast. In the south of the county the strike swings round to east-north-east—west-south-west.

The Reading Beds are found under the London Clay in all the borings where the latter occurs, but in a few cases they are reached without any intervening London Clay. The thickness is more constant than that of the overlying beds and varies generally from 20 to 50 ft. (1), although at Lowestoft it amounts to 75 ft. (8).

Cretaceous.

Chalk.

Upper Chalk exists under the whole of the county. The highest beds of this division are probably always absent, but 551½ ft. of Upper Chalk is recorded from Stutton (6). In this boring a thickness of 178½ ft. was assigned to the Middle Chalk, but in the three other deep borings quoted in the following table no separation of Middle from Upper Chalk was possible. The Lower Chalk is 158½ ft. thick at Stutton and 143 at Culford (*Quart. Journ. Geol. Soc.*, vol. l, 1894, p. 495).

The total thickness of the Chalk is given by two borings only, namely, Stutton, 874 ft., and Lowestoft, 1,050 ft. (8).

The surface of the Chalk in the south of the county slopes to the east-south-east, but north of a line from Needham Market to Aldeburgh it swings round an easterly slope. Inland the slope is scarcely perceptible, but near the coast it steepens to 1 in 50.

Gault.

The Gault is remarkably thin, being 50 ft. at Stutton, 73 ft. at Culford (6), and 56 ft. thick (including 11 ft. of Upper Greensand) at Lowestoft (8).

Lower Greensand.

The Lower Greensand is absent at Stutton, but was proved to be 32½ ft. thick at Culford (6), and 41 ft. at Lowestoft (8). In these three borings Lower Palæozoic rocks were reached.

To face page 128.

SOME BORINGS IN SUFFOLK, ARRANGED FROM SOUTH TO NORTH. (*Thicknesses in feet.*)

	Brantham.	Stutton	East Bergholt.	Shotley.	Felixstowe.	Glemsford.	Brettenham Park.	Woolverstone.	Ipswich.	Ipswich.	Westerfield.	Woodbridge.	Woodbridge.	Boulge.	Ashbocking.	Coombs.	Kirton.	Bawdsey.	Orford Marshes.	Lantern Marshes, Orford.	Melton.	Culford.	Mildenhall.	Benhall.	Leiston.	Saxmundham.	Saxmundham.	Kelsale.	Bramfield.	Euston.	Fressingfield.	Southwold.	Kessingland.	Beccles.	Lowestoft.	Oulton Broad.
Alluvium	1	16	—	—	2	—	—	2	—	—	—	2	3	—	—	—	—	2		20	63	—	1	—	—	—							1	1	—	
Glacial	—	—	—	—	—	470	312	16	127	35	27	35		49	135	57	—	—		—		6	—	52	36	—	103	106	70	to 224	72	37	70	28	70	48
Norwich Crag ...	—	—	—	17	—	—	—	—	—	—	25	95	84	50	—	—	—	—	100	—		—	—	—	—	—					204					
Red Crag	—	—	—		17	—	—	—	—	—					$4\frac{1}{2}$	—	—	14		10	11	—	—	22	134	105	63	45	53	—		147	100	128	170	194
London Clay ...	55	54	113	8	$83\frac{1}{2}$	—	—	59	—	—	25	20	36	56	—	—	110	87	78	129	17	—	—	35	74	—	—	—	6	—	—	68	—	—	160	to 73
Reading Beds ...	49 to 95		57 to 88	45 to 30	53 to 343	— to 40	— to 232	$34\frac{1}{2}$ to 144	— to 81	— to 240	30 to 80	41 to 55	35 to 119	40 to 29	— to 120	— to	44 to 48	46 to 150	46 to 96	50 to 70	35 to 224	— to	— to	41 to 151	53 to 189	21 to 53	— to 65	— to 70	36 to 84	— to	— to 110	71 to 256	— to	— to 130	75	—
Upper Chalk ...	—	556	88	30	343		232	144	81	240	80	55	119	29	120		48	150	96	70	224	383	—	151	189	53	65	70	84	—	110	256	—	130		—
Middle Chalk ...	—	164	—	—	—		—	—	—	—	—	—	—	—	—	$843\frac{1}{2}$	—	—	—	—	—		251	—	—	—	—	—	—	—	—	—	—	—	1050	—
Lower Chalk ...	—	$154\frac{1}{2}$	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	143		—	—	—	—	—	—	—	—	—	—	—		—
Gault	—	$49\frac{1}{2}$	—	—	—	—	—	—	—	—	—	—	—	—	—	to 21	—	—	—	—	—	73	to 20	—	—	—	—	—	—	—	—	—	—	—	56	—
Lower Greensand ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	$32\frac{1}{2}$ to 20	—	—	—	—	—	—	—	—	—	—	—	—	41 to 205	—
Palæozoic	—	$531\frac{1}{2}$	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—		—

SURREY AND SUSSEX.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Blown Sand, Shingle, Alluvium ...	—
	Raised Beach, Valley Gravel, Clay with Flints	—
	Plateau Gravel. Coombe Rock ...	—
Pliocene ...	Lenham Beds	seen to 12
Eocene ...	Barton, Bracklesham and Bagshot Beds	up to 450
	London Clay	about 200
	Blackheath Beds	0–40
	Woolwich and Reading Beds	30 to over 100
	Thanet Sand	0–35
Cretaceous	Chalk (Upper, Middle and Lower) ...	530 to over 1,200
	Upper Greensand, Gault ... ... } Selbornian ...	217–403
	Lower Greensand: Folkestone Beds	0–490
	Lower Greensand: Sandgate Beds	
	Lower Greensand: Hythe Beds	
	Lower Greensand: Atherfield Clay	
	Weald Clay	0–1,000
	Hastings Beds: Tunbridge Wells Sand with the Grinstead Clay	up to about 1,100
	Hastings Beds: Wadhurst Clay	
	Hastings Beds: Ashdown Beds or Sand with the Fairlight Clay	
Oolitic ...	Purbeck Beds	up to 466
	Proved in borings only :—	
Oolitic ...	Portland Beds	up to 141
	Kimmeridge Clay	up to 1,290 ?
	Corallian Beds	up to 222 ?
	Oxford Clay	proved to 120
Palæozoic Rocks	... ...	—

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Superficial.

The only superficial deposit deserving special mention is the 'Coombe Rock' of Sussex. This is a 'faintly-stratified deposit of unworn or shattered flints mixed with Chalk, which occupies the lower part of the valleys in the Downs and spreads out in a wide sheet over the maritime plain' (11). At Birling Gap an excellent section showed Coombe Rock fully 30 ft. thick (10), but its thickness, like that of the other superficial deposits, is extremely variable.

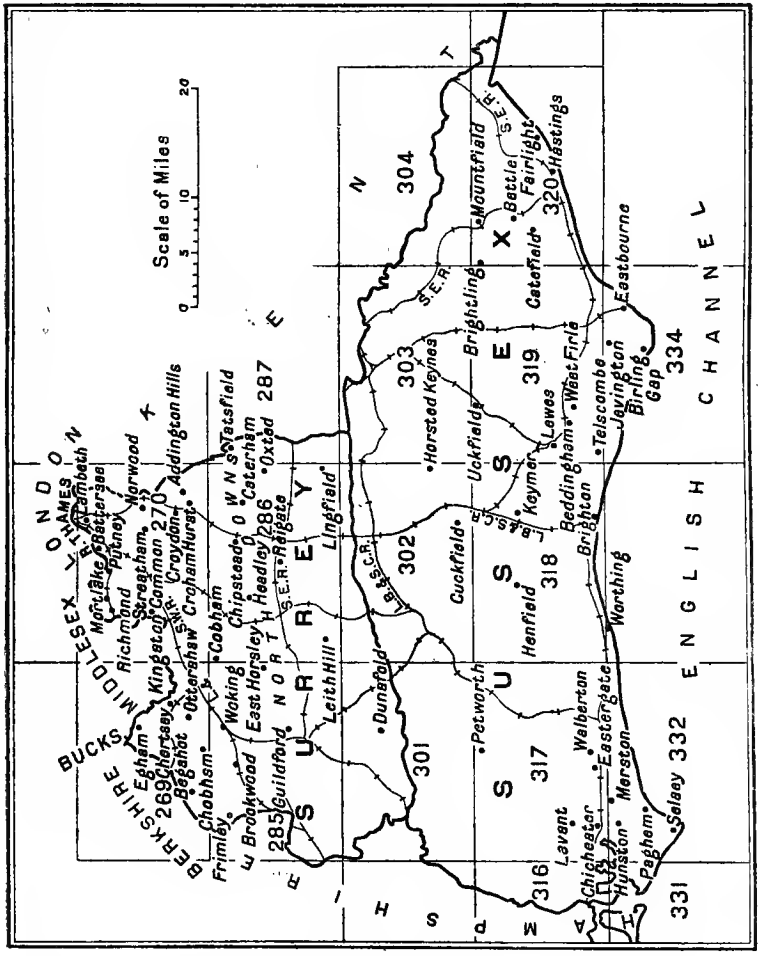

Fig. 30. Surrey and Sussex.

Pliocene.

The Lenham Beds which occur in small patches on the Chalk of Surrey, at Steadley, east of Guildford, and at Chipstead, south of Croydon, consist of patches of yellow sand 5 to 12 ft. thick with a few flint-pebbles, and ferruginous, or occasionally glauconitic, grit with casts of fossils (8).

Eocene.

Barton, Bracklesham and Bagshot Series.

In Surrey the Barton Beds, shown on the Old Series Geological Map, Sheet 8, as 'Upper Bagshot Sand,' form a number of outliers, in none of which is their full thickness represented.

The Bracklesham Beds under these outliers, where alone they are fully present, consist of loams, laminated clays and green sands, with lignite and ironstone. They vary in thickness from 40 to 50 up to 65 ft. In the Brookwood boring they attained 65 ft., and in the Ottershaw boring may have been 89 ft. in thickness, but this is exceptional and the record seems to require confirmation.

The Bagshot Beds, or the 'Lower Bagshot Sand' of Sheet 8, are composed of white and crimson sands with occasional beds of loam and clay, and local developments of pebble-gravel. The thickness probably seldom exceeds 120 ft. In the Ottershaw boring 124 ft. are assigned to the Bagshot Beds, on the supposition that the Bracklesham Beds were 89 ft. thick.[1]

A well at Bagshot reached, below 9 ft. of gravel, what was judged to be the top of the London Clay at a depth of 454 ft. and was carried a further depth of 192 ft. in the clay (14).

In Sussex the Bagshot Sands are thin and inseparable from the Bracklesham Series. A boring at Selsey starting in the latter reached the London Clay at 360 ft. and proved the Bracklesham Series to consist of green and black sands and clays. Their total thickness is estimated to be 500 or 600 ft. (12).

London Clay.

In Surrey the London Clay varies in thickness from 400 ft. (Chobham) to 371 ft. (Brookwood) and 336 ft. (Ottershaw).[1] At Cobham between undoubted London Clay and undoubted Reading Beds there occurred 100 ft. of 'coloured grey clay,' somewhere within which presumably lies the junction of the two formations.

In Sussex the full thickness of London Clay and Reading Beds was proved at Hunston to be 233 ft. (12), of which presumably about 70 or 80 ft. may be assigned to the Reading Beds. At Eastergate the thickness of the London Clay was proved to be more than 208 ft. (12), and at Merston more than 292½ ft.

Blackheath Beds.

These sands and pebble-beds, which are developed in north-western Kent, are known to occur in the north-eastern part only of Surrey. They may be seen at Croham Hurst, the Addington Hills, and other spots near Croydon. In wells at the last-named place they vary from 12 to 37 ft. in thickness. At Caterham a deep pipe in the Chalk, filled with Blackheath pebble-beds, was encountered.

Woolwich and Reading Beds and Thanet Sand.

In Surrey the Woolwich and Reading Beds comprise white or crimson sands and mottled clays, mostly of a bright colour. They

[1] 'The Country around Windsor and Chertsey,' *Mem. Geol. Surv.*, 1915, p. 112.

contain also pebble-beds and some lignite. At their base is a greenish sand with worn or unworn flints. The Thanet Sand is not recognisable in western Surrey and is seldom easy to define precisely in borings in the central and eastern parts of the county.

Near Egham, Chertsey, Chobham, Frimley and Woking, the strata between the London Clay and the Chalk are all assigned to the Woolwich and Reading Beds, and vary in thickness from 68 ft. (Frimley) to 104 ft. (Chertsey). At Kingston, Putney, Mortlake, Lambeth and Battersea, the thickness ranges from 73 to 108 ft., in which are included 20 to 30 ft. of Thanet Sand. At Norwood an aggregate thickness of 71 to 97 ft. includes 29 to 38 ft. of Thanet Sand.

In Sussex the Woolwich and Reading Beds are mainly clays. At Chichester, in a brewery well, there were 97 ft. of mottled clays belonging to this series; at Eastergate, 109 ft. 6 ins.; at Fishbourne (a mile west of Chichester Cathedral), 106½ ft.?; at Merston (Bognor Waterworks), 99 ft. 6 ins.; at Pagham, 104 ft.; at Walberton, 148 ft.?; and at Worthing, 102 ft. (12).

Cretaceous.

Chalk.

In Surrey the total thickness of the Chalk is shown in the Table following p. 134 as 646 ft. by the Ottershaw boring,[1] near Chertsey, 670 ft. by the Richmond boring, 623 ft. by the Streatham Common boring, and 817½ ft. by the East Horsley boring (14). The Chalk Rock, which forms the base of the Upper Chalk, is not well developed, but the Melbourn Rock at the base of the Middle Chalk occurs in characteristic nodular form, with a thickness of about 8 to 12 ft.

In Sussex the whole of the Chalk is traversed by a boring at Chichester. The thickness was ascertained to be 790 ft., of which 604 ft. was believed to consist of Upper and Middle Chalk (12). At East Lavant the total thickness bored through was more than 1,012 ft., of which 597½ ft. were attributable to Upper Chalk, 212½ ft. to Middle Chalk, and 202 ft. to Lower Chalk. The boring started about 200 ft. below the top of the Chalk. The thickness of the Upper Chalk therefore must be about 800 ft., and that of the whole formation about 1,212 ft.

At Telscombe, near Brighton, a boring started a little below the top of the Chalk and proved Upper Chalk, 418 ft.; Middle Chalk, 212 ft.; Lower Chalk (including possibly some of the Upper Greensand), 328 ft. The total thickness is thus about 958 ft., which is a probable amount, but the proportion assigned to the Lower Chalk seems excessive.

The variations in the thickness of the Upper Chalk are largely due to pre-Tertiary denudation, but there is, apart from this, a general thickening from north to south through Surrey and Sussex.

Upper Greensand and Gault (Selbornian).

The Selbornian rises from beneath the Chalk in a narrow outcrop at the foot of the North Downs. The Upper Greensand, with a thickness of 16 to 35 ft., passes down into a sandy marl and so

[1] 'The Country around Windsor and Chertsey,' *Mem. Geol Surv.*, 1915, p. 112.

into the stiff clay which constitutes the Gault. It contains an abundance of grains of glauconite and varies in character from sand to calcareous sandstone.

In Surrey the greatest thickness of Gault yet met with amounted to 343 ft., and was proved at Caterham, and the total thickness of Selbornian was there 377½ ft. as compared with 278 ft. at Ottershaw.[1] At Richmond and Streatham the Selbornian was only 217 ft. thick.

In Sussex, at Beddingham, near Lewes, a boring starting in the Upper Greensand passed through 28 ft. of that formation, 310 ft. of Gault Clay, and 6 ft. of Lower Greensand. Another at West Firle, 4½ miles south-east of Lewes, proved the Gault to be not less than 327 ft. thick. At Eastbourne one boring only has traversed the whole of the Upper Greensand, with the result of proving that it is 47 ft. thick and that the Gault is not less than 261 ft. thick (13). In another case the thickness of undoubted Gault was ascertained to be 286 ft., but there is a doubt whether some of the underlying strata should not also have been included in the Gault. At Telscombe the thickness of Upper Greensand and Gault was respectively 10 ft. and 312 ft. At Chichester the Upper Greensand was proved to be not less than 84 ft. thick. The greatest thicknesses of Gault were found at West Firle (327 ft.) and at Jevington (345 ft.), in both cases the top being absent.

It would appear from these figures that the average thicknesses of the Selbornian in Sussex vary as follows. The thickness of Gault in West Sussex is not known, but is inferred from a comparison of the measurements in Mid-Sussex and Hampshire:—

	West Sussex.	Mid-Sussex.	East Sussex.
	Feet.	Feet.	Feet.
Upper Greensand	not less than 84.	10	28–47
Gault	250 (supposed)	312–327	310–286
Total of Selbornian ...	about 300	332	338–333

Lower Greensand.

In Surrey this formation is absent in the north-eastern part, as for example at Streatham, but is present in an attenuated form at Richmond and Chertsey, and has been found also at Slough in Buckinghamshire. Southwards it expands and includes the following subdivisions in descending order (2 and 14):—

	West Surrey. Feet.	East Surrey. Feet.
Folkestone Beds, essentially a sand-formation, loose and coarse in grain	120 to nearly 300	100
Sandgate Beds, fine-grained sand and clay...	not distinguishable.	40
Hythe Beds, sand, sandstone and chert, calcareous beds in the upper part ...	200–300	152–180
Atherfield Clay	60	30

[1] 'The Country around Windsor and Chertsey,' *Mem. Geol. Surv.*, 1915, p. 112.

A boring near Reigate traversed 297 ft. of sand with but little clay. There was nothing to distinguish the strata from Folkestone Beds, but it was presumed that the boring touched a lower subdivision. The same remark applies to strata recently proved at Kingscote Mill, near Dorking, where a boring starting in yellow, red and white sands did not reach their base at a depth of 300 ft. Near Reigate the Atherfield Clay was proved to be 55 ft. thick (2 and 14). At Oxted the Sandgate Beds, as supposed, were 30¼ ft. thick and the Hythe Beds 152½ ft. (14). At Tatsfield the Folkestone Beds were 211 ft. and the Sandgate Beds, as supposed, 6½ ft. thick (14), but the base of the Folkestone Beds could not be fixed precisely, and it would be safer to say that the Folkestone and Sandgate Beds together were 217½ ft. thick.

In Sussex the Lower Greensand is sometimes absent or doubtfully represented, as for example at Eastbourne Waterworks and at Jevington (12). In its absence the Gault rests on Weald Clay. At West Firle, near Lewes, the Lower Greensand is 12 ft. thick, and thence expands rapidly westwards. In Mid-Sussex, at Henfield, a boring proved Folkestone Beds (top absent) 57 ft., Sandgate Beds, 126 ft., and touched what may have been Hythe Beds (12 and 13). In West Sussex the greatest thicknesses attained are estimated to be:—Folkestone Beds, about 140 ft.; Sandgate Beds, 100 ft.; and Hythe Beds, 200 ft. (12, p. 4). A boring at Petworth House shows the thickness of the Atherfield Clay there to be 50 ft. Thus the thickness of the Lower Greensand as a whole in West Sussex is about 490 ft.

Wealden Beds.

This formation includes:—

		Feet.
Weald Clay, brown or blue clay or shale and stone-bands, with mottled clays and subordinate sand-beds		1,000
Hastings Beds.	Tunbridge Wells Sand (with Cuckfield Clay and Grinstead Clay)	160–380
	Wadhurst Clay	136–227
	Ashdown Sand	74–293
	Fairlight Clay, upwards of	388

In Surrey the Wealden Beds are absent towards the north as shown by the borings at Richmond and Streatham, but they come in southwards with rapidly increasing thickness. The greatest thickness proved in a boring was met with at Dunsfold.

Of the 1,201 ft. there traversed 900 ft. at least may be assigned to the Weald Clay, and the remainder with some doubt to the Hastings Beds. The thickness of the Weald Clay had previously been estimated to lie between 900 to 1,000 ft. near Leith Hill, but to diminish thence both eastwards and westwards (2).

A small part only of the outcrop of the Hastings Beds falls within Surrey. The various subdivisions into which this group of strata is separable in Sussex are often difficult to recognise in borings, but the following figures may be quoted (14). At Lingfield a boring passed through 60 ft. of Tunbridge Wells Sand, 34 ft. of Grinstead Clay and 55 ft. of clay, shale and rock. Near Reigate a boring passed through 553 ft. of Weald Clay and was carried for a further 357 ft. in Hastings Beds.

To face page 134

SOME BORINGS IN SURREY AND SUSSEX.

(Thicknesses in feet.)

	SURREY.							SUSSEX.							
	Ottershaw[1], Chertsey.	Richmond.	Streatham Common.	Chobham.	Bagshot.	Brookwood (Woking).	Cobham.	East Horsley.	Caterham.	Dunsfold.	Mountfield (Battle).	Battle.	Telscombe (Brighton).	Chichester.	East Lavant (Chichester).
Barton Beds (Upper Bagshot Sand)	—	—	—	100 (part)		3 (part)	—	—	—	—	—	—	—	—	—
Bracklesham Beds	89 ?	—	—	40	445	65	—	—	—	—	—	—	—	—	—
Bagshot Sand	124 ?	—	—	100 (or more)		105½	80 (part)	—	—	—	—	—	—	—	—
London Clay	336	160 (part)	153 (part)	400	o 192	371	462[2]	—	—	—	—	—	—	60 (part)	—
Blackheath Beds	—	—	—	—	—	—	—	—	89 (part)[3]	—	—	—	—	—	—
Reading Beds	100	59½	? 43½	50	—	89½	42	—	—	—	—	—	—	97	—
Thanet Sand	—	22½	35	—	—	—		20 (part)	—	—	—	—	418	—	—
Chalk... Upper	646[1]	300	221½	to 150	—	to 250	to 66	817½	349	—	—	—	212	604	1012
Chalk... Middle		150 (about)	219	—	—	—	—			—	—	—	328[4]	186	(part)
Chalk... Lower		220 (about)	182½	—	—	—	—	17½	34½	—	—	—	10	to 84	—
Upper Greensand	278	16	28½	—	—	—	—	to 6	343	—	—	—	312	—	—
Gault		201½	188½	—	—	—	—		to 30	—	—	—	to 5	—	—
Lower Greensand	to 12	10	—	—	—	—	—	—	—	to 1201	—	—	—	—	—
Wealden ... Weald Clay	—	—	—	—	—	—	—	—	—		—	345 (part)	—	—	—
Wealden ... Hastings Beds	—	—	—	—	—	—	—	—	—	—	168⅓ (part)	466	—	—	—
Purbeck Beds	—	—	—	—	—	—	—	—	—	—	105⅔	141	—	—	—
Portland Beds	—	—	—	—	—	—	—	—	—	—	1290 ?	to 1114	—	—	—
Kimmeridge Clay	—	—	—	—	—	—	—	—	—	—	222 ?	—	—	—	—
Corallian	—	—	—	—	—	—	—	—	—	—	to 120 ?	—	—	—	—
Oxford Clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Great Oolite Series	—	87½	38½	—	—	—	—	—	—	—	—	—	—	—	—
Palæozoic	—	to 207½	to 151	—	—	—	—	—	—	—	—	—	—	—	—

[1] 'Coun ry around Windsor and Chertsey' (*Mem. Geol. Surv.*).
[2] Including 100 feet of coloured grey clay, part of which may be Reading Beds.
[3] Occupying a deep pipe in the Chalk.
[4] Probably including some Upper Greensand.

In Sussex the Weald Clay has been proved to exceed 200 ft. in thickness at Eastbourne and 376 ft. at Keymer (12).

The Tunbridge Wells Sand with the Cuckfield and Grinstead Clays have a combined thickness varying from about 160 ft. in the east to 380 ft. near Cuckfield (2). The Wadhurst Clay is known to be 136 ft. thick at Catsfield, 180 ft. at Uckfield, and 227 ft. at Cuckfield (12). The Ashdown Sand has been proved to be 74 ft. 8 ins. thick at Fairlight, and 293 ft. 6 ins. at Horsted Keynes. The greatest thickness proved of the Fairlight Clay is 388 ft. 3 ins., at Hastings Waterworks, where, however, its base was not reached. The total of the above maximum thicknesses of the subdivisions amounts to 1,288 ft. 9 ins. Should the Fairlight Clay (unlike the higher beds) decrease in thickness westward the total thickness of the Hastings Beds in Sussex is not likely to be less, on the average, than 1,100 ft. or thereabouts.

Oolitic.

In Surrey strata of Oolitic age have been proved to exist by the borings at Richmond and Streatham Common. Northwards, in Middlesex and Buckinghamshire, they are known to be absent; but, on the other hand, southwards in Sussex and eastwards in Kent they attain a considerable development.

At Richmond the Oolitic strata were 87½ ft. thick and were all assigned to the Great Oolite Series; those at Streatham were 38½ ft. thick and were assigned with doubt to the Forest Marble subdivision of the same series. Beyond the general probability that the Jurassic rocks are likely to be present, nothing can be said at present with regard to their development under the southern part of Surrey.

In Sussex the Purbeck Beds crop out in a small area near Brightling and Battle. They were proved in a boring near Battle to be 466 ft. thick, under 345 ft. of Hastings Beds. A previous boring at Mountfield, usually known as the Sub-Wealden Exploration, had started in the Purbeck Beds and had been carried down into the Oxford Clay as shown in the preceding Table.

WARWICKSHIRE AND WORCESTERSHIRE.

Table of Strata.

			Thickness in feet.
Superficial		Alluvium	to 20
		Glacial	to 130
Oolitic		Great Oolite Series	to 100
		Inferior Oolite Series	to 180
Liassic		Upper Lias	100–120
		Middle Lias	250–280
		Lower Lias	960
Triassic		Rhaetic	30–50
	Keuper	Marl	600–1,000
	Keuper	Sandstone	up to 400
	Bunter	Upper Mottled Sandstone	to 215
	Bunter	Pebble Beds	to 350
	Bunter	Lower Mottled Sandstone	—
Palæozoic and older rocks			—

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3. H. B. Woodward. Victoria History of the Counties of England, Worcestershire, 1901.
4. T. C. Cantrill, *ib.*, Warwickshire, 1904.
5. C. A. Matley, *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 252.

SUPERFICIAL.

Alluvium.

Alluvial deposits occupy no great part of Warwickshire or Worcestershire and do not appear to exceed 20 ft. in thickness (3, 4).

Glacial.

The Glacial beds are best developed in the northern parts of the counties and around Rugby (1), where they are, in places, over 100 ft. thick (Table, p. 139). Generally, however, they do not exceed 50 ft. Over large areas the solid rocks form, or are near, the surface.

OOLITIC.

The highest of the Mesozoic strata existing in these counties is a small outlier of the Great Oolite Series in a detached part of Worcestershire, near Daylesford.

The Inferior Oolite Series consists of clays, sands and oolitic limestones and has an estimated maximum thickness of 180 ft. (3, 4).

LIASSIC.

The Upper Lias occupies small areas in the south-east of the counties, where its thickness is estimated as being between 100 and 120 ft. (3, 4). It ‘ is for the most part a clay formation,

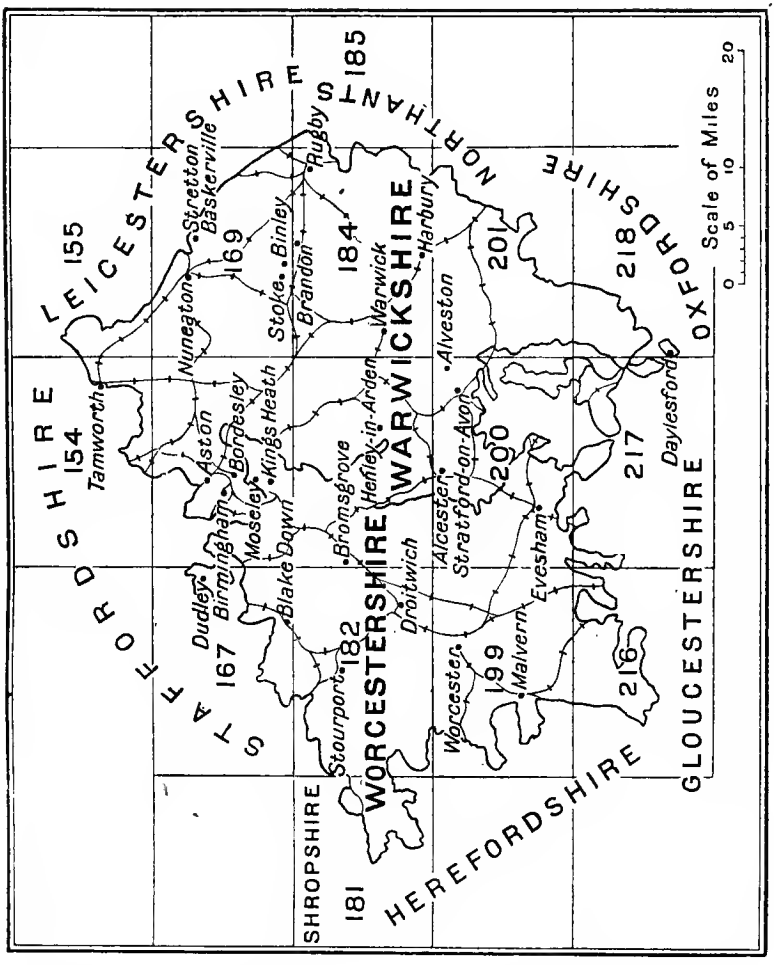

Fig. 31. Warwickshire and Worcestershire.

having occasional nodules of limestone. A few more persistent bands of limestone occur at the base, and these are associated with about 20 ft. of paper shales which are slightly bituminous.' (3).

The Middle Lias has also a narrow outcrop and is from 250 to 280 ft. thick (3, 4).

'It is a somewhat variable formation, . . . the lower part comprising micaceous loams, clays and sands, while the upper part is a rock bed of ferruginous and sandy limestone, sometimes termed the Marlstone, . . . which is 8 or 10 ft. thick' (3).

The Lower Lias 'consists of a group of argillaceous limestones, overlain by a thick mass of blue and grey clays with only occasional bands of limestone' (3). It is found in the south and south-east of the counties from Rugby to Stratford-on-Avon and in the ground between Worcester, Droitwich and Alcester.

In Gloucestershire, near the border, the Mickleton boring (see p. 62) proved 961 ft. of clays and limestones, and this probably represents the average thickness of the Lower Lias of Warwickshire and Worcestershire (1, 3).

Triassic.

Rhaetic.

The Rhaetic Beds consist of limestones, clays and black shales and are about 30 ft. thick (3). Some estimates range up to 50 ft., but these probably include some of the green uppermost beds of the Keuper Marl (4).

Keuper.

The Keuper Marl varies from about 600 to 1,000 ft. in thickness (3, 4). At Moxhull a boring is reported to have traversed 700 ft. of the marl without reaching the base. At Rugby Rhaetic Beds were reached at a depth of 468 ft. (1), and the base of the Keuper Marl at 1,140 ft. The combined thickness of the Rhaetic and Keuper Marl was therefore 672 ft., of which not less than 10 ft. may be assigned to the Rhaetic. At King's Heath (p. 139) the thickness of the marls exceeds 611 ft. (J. Harrison, *Geol. Mag.*, 1886, p. 453), and at Stoke Prior Salt Works a shaft commencing below the top of the marls proved 460 ft. of them without reaching their base (R. I. Murchison, 'Silurian System,' p. 31).

About 100 to 120 ft. below the top of the Marls there are 30 ft. of coarse grey sandstones and bluish-green shales known as the Upper Keuper or Arden Sandstones (5).

The Lower Keuper Sandstone is one of the chief water-bearing strata of the district, and is known to exceed a thickness of 300 ft. at Bromsgrove and 250 ft. at Stretton Baskerville. Further to the south-east it is less well developed, and in places, as on the east of the Warwickshire inlier of Palæozoic Rocks, it is overlapped by the Keuper Marl.

Bunter.

The Bunter, also a notable source of underground water, attains its greatest development in the north-western parts of the counties, and is believed to be absent south-east of a line drawn a little south of Stourport, Bromsgrove and Birmingham to Tamworth.

A well at Ansell's Brewery, Aston, starting in Keuper Sandstone, reached the top of the Bunter at 192 ft. and the base at 435 ft., showing the thickness to be 243 ft., but at Burcot, N.E. of Bromsgrove, in a well which started in Bunter, the depth to the base was upwards of 400 ft.

The Upper Mottled Sandstone has a thickness of more than 215 ft. at Bromsgrove and the Pebble Beds are estimated to be 350 ft. (4).

The Lower Mottled Sandstone has been estimated to be 650 ft. thick at Bridgnorth (Shropshire),[1] but thins out south of Stourport.

[1] 'The Triassic and Permian Rocks . . . ,' *Mem. Geol. Surv.*, 1869, p. 32.

PRINCIPAL BORINGS IN WARWICKSHIRE AND WORCESTERSHIRE. (Thicknesses in feet.)

One-inch Sheets (New Series).	167.	168.				169.			183.	184.				199.	200.	
	Blakedown (Mary Knoll).[1]	Aston.	Bordesley.	King's Heath.	Moseley.	Stretton Baskerville.	Stoke.	Binley.	Bromsgrove.	Brandon.	Rugby.	Warwick.	Harbury.	Malvern Link.	Stratford-on-Avon.	Alveston.
Alluvium and Glacial ...	—	12	30	56	9	130	—	10	—	21	10	—	—	2	—	12
Lower Lias	—	—	—	—	—	—	—	—	—	—	458	—	106	—	—	—
Rhaetic	—	—	—	—	—	—	—	—	—	—	10	—	48	—	—	—
Keuper Marl	—	—	—	611 to	475 to	242	60	235	—	277	662 to	370 to	290	705 to	604 to	537 to
Keuper Sandstone ...	34	—	87	91½	243½	250½	82	64	300 to	36	5	104	—	173	200	205
Upper Mottled Sandstone	200 to	63	109	—	—	—	—	—	215	—	—	—	—	—	—	—
Pebble Beds	66	169 to	154 to	—	—	— to	— to	— to	—	— to	—	—	—	—	—	—
Carboniferous and Older Rocks.	—	174	31	—	—	58½	27	615	—	32	—	—	—	—	—	—

[1] Information from W. Wickham King.

WILTSHIRE.

Table of Strata exposed and proved in borings.

		Thickness in feet.
Superficial	Alluvium, Valley Gravels, &c.	to 20
Eocene	Lower Bagshot Sands	50 (top not seen)
	London Clay	0–150
	Reading Beds	15–66
Cretaceous	Upper Chalk	200–790
	Middle Chalk	80–150
	Lower Chalk	180–250
	Upper Greensand	50–160 } 150–
	Gault	70–90 } 250
	Lower Greensand	0–40
	Wealden	0–30
Oolitic	Purbeck Beds	0–85
	Portland Beds	0–105
	Kimmeridge Clay	0–450
	Corallian	0–120
	Oxford Clay	500
	Kellaways Beds	10–60
	Cornbrash	15–20
	Forest Marble	50–100
	Great Oolite	to 160
	Fullonian	65–150
	Inferior Oolite	25–40
	Midford Sand	40–100
Liassic	Upper, Middle, Lower	450

Proved in borings only :—

Triassic	Rhaetic	34
Palæozoic Rocks		—

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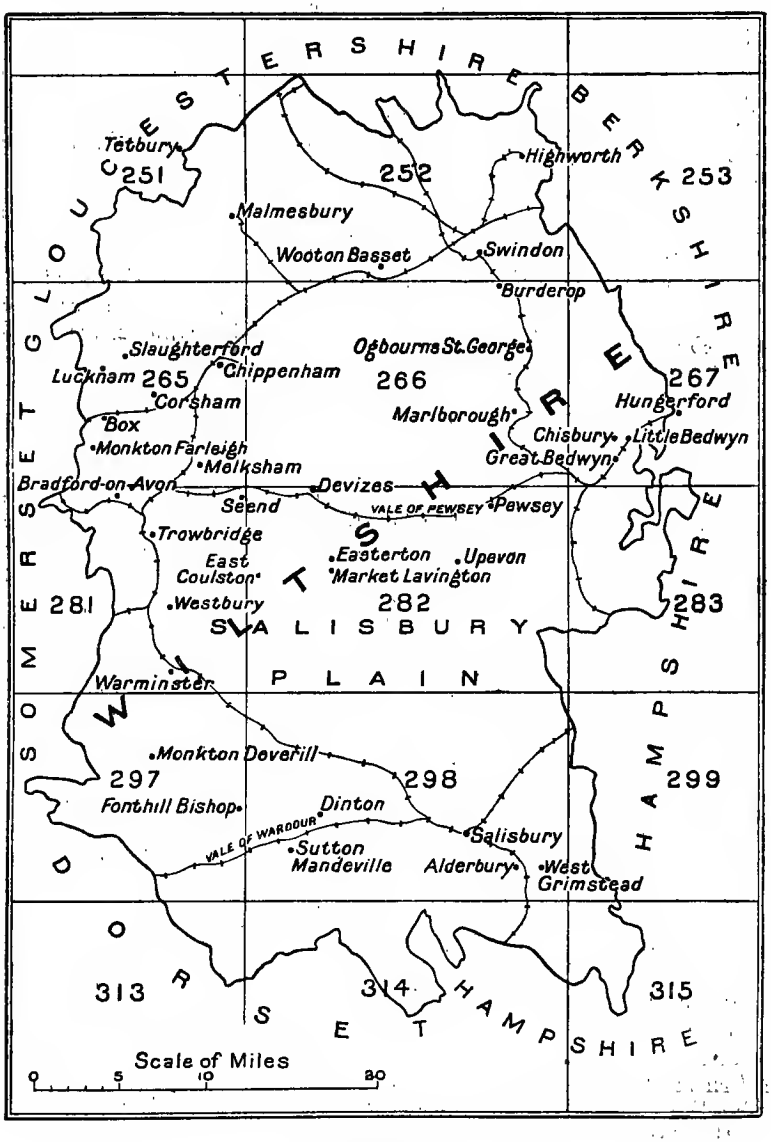
Superficial.

Alluvium, etc.

The Superficial Deposits reach no great thickness. Near Salisbury, at Wadden Farm, the valley-gravels proved to be 20 ft., and in a well at Chippenham town, 18 ft. thick.

Fig. 32. Wiltshire.



Eocene.

Bagshot Beds.

The Bagshot Beds occur in the south-east, between Alderbury and West Grimstead, and, as small outliers, in the Hungerford

district. Nowhere is the full development reached, and over most of the area the thickness is inconsiderable; near Alderbury it has been estimated at 50 ft. (7).

London Clay.

The thickness of the London Clay is greatest in the south-east, near Alderbury, where it is given as 150 ft. (7). Further north, the Hungerford outliers indicate either a rapid attenuation in a north-westerly direction or else the replacement of the clay by sands of Bagshot type. Thus at Kirby House (Berks) the clay proved to be 46 ft. thick (9), near the Bedwyns 12 or 15 ft. (2), and at Leigh Hill it is represented only by a few inches of black flint-pebbles. At Chisbury Camp the London Clay is absent and sands of Bagshot type rest directly on Reading Beds (9).

Reading Beds.

A thickness of 50 ft. has been assigned to the Reading Beds near Alderbury (7), and over the greater part of the Hungerford area it is stated to vary between 60 and 80 ft. (9). Near the Bedwyns, however, it falls to 12 to 15 ft., indicating an attenuation analogous to that noted in the London Clay.

Cretaceous.

Chalk.

As the plane on which the Lower Tertiary Beds were deposited cuts across the gently dipping Chalk, it reaches a lower horizon in the north-west than in the south-east. Consequently the highest zones of the Chalk occur only in the Salisbury district bordering the Eocene Area. Here the thicknesses of the zones of the Upper Chalk are given as follows (7):—

	Feet.
Zone of *Belemnitella mucronata*...	70–80
„ *Actinocamax quadratus*...	170
„ *Marsupites*	230
„ *Micraster coranguinum*	230–250
„ *Micraster praecursor* and *Holaster planus* ...	70

making a total of about 790 ft. But over most of the eastern part of Salisbury Plain no greater thickness than 550 ft. is developed (8), and on the south side of the Vale of Pewsey, where no zone occurs higher than that of *Micraster coranguinum*, it falls to 200 ft. On the north side of the vale the thickness below the Eocene cannot be more than 300 ft. (12).

The Middle Chalk is thinnest in the southern and western parts of the county. Near Monkton Deverill, at Lower Pertwood Farm, a boring showed it to be only 80 ft., and at Westbury and Warminster it has been estimated at 90 ft. At Warminster, a section in Arn Hill Quarry shows thicknesses of 48½ ft. for the *Terebratulina* Zone and 31 ft. for the *Rhynchonella cuvieri* Zone, excluding the Melbourn Rock. Northwards the sub-division thickens from 100 ft. at Devizes to 140 ft. at Swindon, and in the south-eastern part of the Vale of Pewsey reaches 140 to 150 ft. (11).

The Lower Chalk thickens northwards in a like manner; at Shaftesbury it is 180 ft. thick, increasing to 200 ft. in the Vale

of Wardour and to 250 ft. at Warminster. In the Devizes district it has been estimated at 250 ft., of which 170 ft. may belong to the *Ammonites varians* Zone and 80 ft. to that of *Holaster subglobosus* (8). At the boring at Pond Farm, Easterton, the probable thickness is 253 ft.

Upper Greensand and Gault.

The Upper Greensand varies irregularly in thickness. Thus, in the Vale of Wardour and at Warminster it is estimated at 150 to 160 ft., decreasing to 80 or 90 ft. at Westbury, to thicken to 150 ft. at Devizes, while at Pond Farm, Easterton, a boring proved it to be 165 ft. thick. Northwards it again decreases till at Calne it is only 50 to 70 ft. (10). The variations in the relative thicknesses of Gault and Upper Greensand are largely due to the fact that the one graduates into the other and that it is not possible to draw a lithological boundary between them at a constant horizon.

The lower part of the Selbornian, the Gault, has a uniform thickness of 70 to 90 ft. over the greater part of the county. In the north-east, however, it must expand considerably, in view of the fact that it is 229 ft. thick in the Wantage district in Berkshire.

Lower Greensand.

Resting unconformably on the Jurassic rocks and itself overlapped by the Gault, this formation is of variable thickness and is frequently absent. In the Vale of Wardour, at Dinton, a well proved it to be 26½ ft. (7), and from this point it thins out westwards to disappear at Fonthill Abbey; on the south side of the vale it attains a thickness of 30 ft. at Totterdale. Northwards it is absent as far as Devizes, but there reaches 40 ft. as a probable maximum. In the Wootton Bassett district, at Broad Hinton, a boring proved it to be 23 ft. thick, and at Swindon it has been estimated at 25 ft.

Wealden.

Clays and marls of this age occur but only in the Vale of Wardour, in the neighbourhood of Dinton and Sutton Mandeville, where their maximum thickness cannot exceed 30 ft. (7).

Oolitic.

Purbeck Beds.

The Purbeck Beds are met with in the Vale of Wardour and in a small outlier near Swindon. Elsewhere their outcrop is hidden by the overlapping Cretaceous, but they may be anticipated to exist beneath Market Lavington, Pewsey, and the Marlborough Downs. They are represented in the Vale of Wardour by marls and limestones with a thickness estimated at 85 ft. (6).

Portland Beds.

The Portland Beds occur as disconnected outcrops in the Vale of Wardour, south of Devizes and again at Swindon, where, from their absence in a boring at Burderop (6) it is deducted that they occur as an outlier, the southern margin of which is concealed

by the Cretaceous. In the Vale of Wardour they are capable of division into an upper group of limestone and a lower group of sands and clays, the thicknesses (at Chilmark) being 67 ft. and 38 ft. respectively. In the Swindon outlier, owing to an unconformable overlap by the Purbeck Beds, the Portland sequence is not complete. It is believed to attain a thickness of 86 ft. 6 ins. (6).

Kimmeridge Clay.

In the Swindon district the thickness of the Kimmeridge Clay has been estimated at 300 ft. (6), and at Toot Hill, between there and Wootton Bassett, a well starting in the clay reached the Corallian at 240 ft. Near Devizes, the full development is probably reached east of Coulston, but at Seend only the lower part of the Kimmeridge Clay occurs, the upper beds having been overlapped by the Cretaceous. A well recently sunk at Marston was commenced about 30 ft. below the top of the Kimmeridge Clay and did not reach the base at a depth of 412 ft. A thickness of 450 ft. may be assigned provisionally to the Kimmeridge Clay of this locality.

Corallian.

The Corallian Beds are thickest on the Dorset borders (120 ft.), whence they thin in a northerly direction. At Westbury they have been estimated at 116 ft. and at Calne 80 ft., but in the Swindon boring only 40 ft. were encountered, while at Wootton Bassett this thickness dwindles to 33 ft., and in Rodbourn Lane to 27 ft. (6). In the Highworth district a well at Reddown showed the full thickness to be 79 ft. (Table).

Oxford Clay with Kellaways Beds.

The Oxfordian of this county comprises the Oxford Clay and a lower group of sandy clays, sandstones and rubbly limestones, known as the Kellaways Beds. The thickness of the Oxford Clay is about 500 ft. over most of the county, and in the Swindon boring, quoted in the Table, was proved to be 510 ft. 7 in. (6). At Foxham, near Chippenham, it was penetrated to 420 ft. without the base being reached.

The Kellaways Beds are thickest in the north, where, at Swindon, they proved to be 62 ft. 2 in. thick. At Chippenham they vary between 42 ft. and 60 ft., and near Trowbridge between 10 ft. and 12 ft. (6).

Cornbrash.

This formation varies between 15 ft. and 20 ft. in thickness; at Melksham Spa in proved to be 20 ft. and at Swindon 18 ft. 3 ins. (5).

Forest Marble.

The Forest Marble (including Bradford Clay) shows a progressive thinning to the north-east. South of Bradford-on-Avon it is from 60 to 100 ft., diminishing to 60 ft. between Corsham and Malmesbury and to 56 ft. 5 ins. at Chippenham (Mr. Brotherhood's well). The Swindon boring terminated, after penetrating 33 ft. of the Forest Marble, in what appeared from the fossils to be Bradford Clay (5).

SOME BORINGS IN WILTSHIRE.

(*Thicknesses in feet.*)

	Royal Flying School, Upavon.	Pond Farm, Easterton.	Whitefield, Ogbourne St. George.	Pewsey Water Works.	Broad Hinton, Wootton Bassett.	Upper Whitehouse.	Dinton.	G.W.R., Swindon.	Reddown, Highworth.	Melksham Spa.	Lucknam.
Bagshot Beds	—	—	—	—	—	—	—	—	—	—	—
London Clay	—	—	—	—	—	—	—	—	—	—	—
Reading Beds	—	—	—	—	—	—	—	—	—	—	—
Upper Chalk	top not seen 280	—	—	—	—	—	—	—	—	—	—
Middle Chalk	to 140?	top not seen 40	—	—	—	—	—	—	—	—	—
Lower Chalk	—	253	top not seen 188	—	top not seen	—	—	—	—	—	
Upper Greensand	—	165	44	top not seen 109	347	top not seen 116	—	—	—	—	—
Gault	—	to 8	—	to 67		49	top not seen 38	—	—	—	—
Lower Greensand	—	—	—	—	23	?13	26½ to 7	—	—	—	—
Wealden	—	—	—	—	—	—	—	—	—	—	—
Purbeck Beds	—	—	—	—	—	—	—	—	—	—	—
Portland Beds	—	—	—	—	—	—	—	—	—	—	—
Kimmeridge Clay	—	—	—	—	to 50	to 13	—	top not seen 64	top not seen 23	—	—
Corallian	—	—	—	—	—	—	—	40	79	—	—
Oxford Clay	—	—	—	—	—	—	—	511	touched	top not seen 274	—
Kellaways Beds	—	—	—	—	—	—	—	62	—	20	—
Cornbrash	—	—	—	—	—	—	—	18	—	20	—
Forest Marble	—	—	—	—	—	—	—	to 33	—	to 37	—
Great Oolite	—	—	—	—	—	—	—	—	—	—	—
Fullonian	—	—	—	—	—	—	—	—	—	—	—
Inferior Oolite	—	—	—	—	—	—	—	—	—	—	—
Lias	—	—	—	—	—	—	—	—	—	—	top not seen 434
Rhaetic	—	—	—	—	—	—	—	—	—	—	34
Carboniferous Limestone	—	—	—	—	—	—	—	—	—	—	to 305

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The Bradford Clay is a band of variable thickness, often absent, as in the case of Monkton Farleigh. South of Bradford it is 10 ft., thinning to 6 ft. at Corsham and from 2 to 6 ft. in the tract between that place and Malmesbury (5).

Great Oolite.

At Tetbury (Gloucestershire) the Great Oolite is 160 ft. thick, and in the Box district it is often as much as 120 ft. But near Bradford it falls to 60 to 80 ft. and wedges away rapidly in a southerly direction, so that it is possible that it may be absent under Southern Wiltshire (5).

Fullonian.

The Fullonian reaches its greatest development in the Combe Monkton district, where it is estimated at 135 to 150 ft. Thence northwards it thins to 65 ft. at Slaughterford (1) and to 84 ft. at Tetbury, in Gloucestershire (5).

Inferior Oolite and Midford Sand (Bajocian).

The Bajocian only enters the county near Bath, where the thickness of the Oolite has been estimated at 25 to 45 ft., and near Bradford, where it has been taken as 40 ft. Near Bath the Midford Sand varies between 40 and 100 ft. (5).

LIASSIC.

The Lias is met with only near Box, where a boring at Lucknam,[1] starting a little below its top, reached Rhaetic Beds at a depth of 434 ft.

TRIASSIC (in a boring only).

Rhaetic.

In the Lucknam boring, Rhaetic beds with a thickness of 34 ft. were found resting directly on Carboniferous Limestone, which were penetrated to 305 ft.[1]

[1] Unpublished MS.

YORKSHIRE (EAST).

Table of Strata.

		Thickness in feet.
Superficial	Alluvium	upwards of 100
	Glacial	up to 189
Cretaceous	Chalk	to 1,450
	Red Chalk	2–30
	Speeton Clay	300
Oolitic	Kimmeridge Clay	500 ?
	Corallian	up to 370
	Oxford Clay	up to 150
	Kellaways Rock	up to 100
	Cornbrash	up to 16
	Upper Estuarine Series	up to 200
	Scarborough or Grey Limestone	up to 104
	Cave Oolite or Millepore Bed	up to 30
	Middle or Lower Estuarine Series	up to 390
	Dogger and Blea Wyke Beds	up to 100
Liassic	Upper Lias	up to 250
	Middle Lias	3–140
	Lower Lias	100–800
Triassic	Rhaetic	20–40
	Keuper and Bunter	to 2,100
Permian	Marls and Limestones	to 1,000
Carboniferous and older rocks		—

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Superficial.

Alluvium.

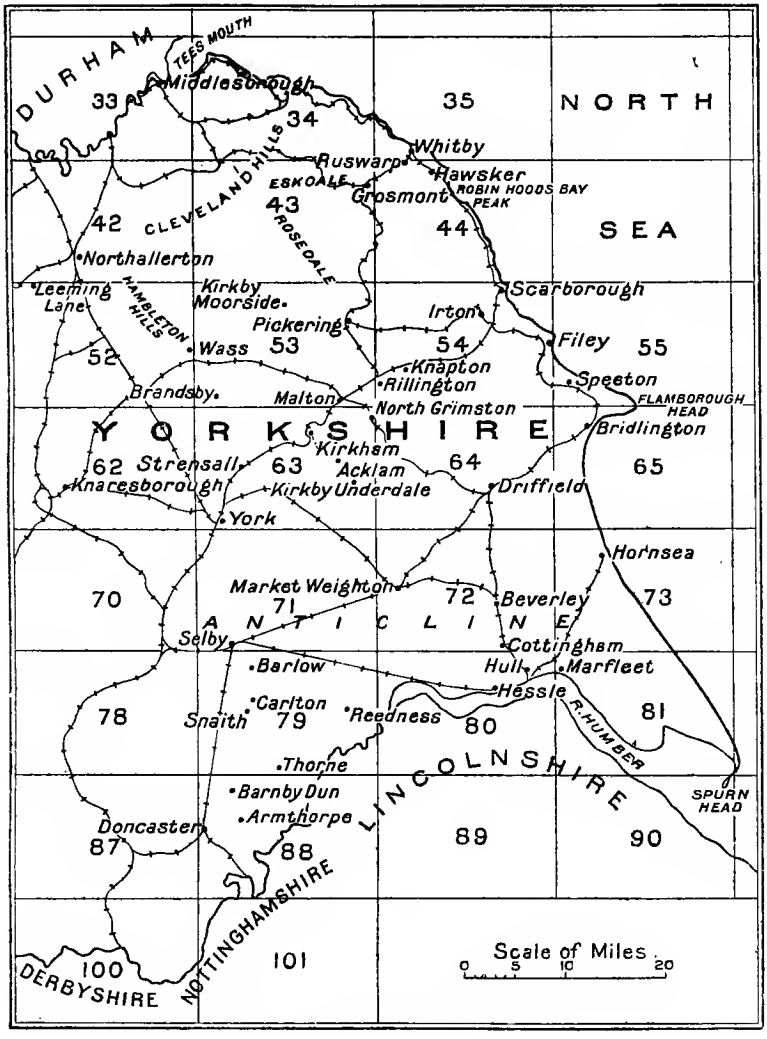
Alluvial deposits occupy large areas and extend to a great depth along the lower reaches of the Derwent through the Vale of Pickering, and of the Ouse and Aire through the Vale of York. A large number of wells has been sunk in them (9).

In the Vale of Pickering mention may be made of a thickness of

79 ft. found at Thornton Dale, 97 ft. at Old Malton and 150½ ft. recorded at Millington.

In the Vale of York it is seldom possible to differentiate the alluvial and the glacial deposits. The two together generally exceed 50 ft. and in places 100 ft. in thickness.

FIG. 33. EAST YORKSHIRE.



Glacial.

On the Holderness Plain the glacial drift varies from as much as 140 ft. in places on the coast to about 50 ft. near a pre-glacial sea-cliff, which runs from Bridlington, through Driffield, Beverley and Cottingham, to Hessle, and is continued in Lincolnshire (2).

Boulder Clay occurs also on the coast north of Flamborough Head. It is 189½ ft. thick at Filey (9), but does not rise above the 800 ft. contour on the Cleveland Hills. On the Chalk Wolds the drift is absent or thin; it is, however, widespread in the Vale

of York, where it fills a buried valley-system, the bottom of which is below sea-level. At York the rock-floor is about 50 ft. below sea-level, at Selby about 90 ft., and at Barnby Dun 170 ft. (10).

Cretaceous.

Chalk.

The Upper Chalk of Yorkshire, which has no flints in the higher beds, has been proved to a thickness of 860 ft. in the southern part of the county.

Estimates of the Middle Chalk in the northern part of its outcrop vary from 150 to 200 ft. (6).

'The thickness of the Lower Chalk in Yorkshire varies considerably. Near South Cave it is about 72 ft.; at the extreme north-west corner of the Wolds . . . it is not more than 60 ft. and possibly less, while at Speeton it attains a thickness of 123 ft. It is evident, therefore, that a rapid diminution of thickness takes place from east to west.' (6).

An estimate of the total maximum thickness of the Yorkshire Chalk is given as 1,450 ft. (6).

Red Chalk and Speeton Clay.

The Red Chalk is 30 ft. thick at Speeton but thins gradually to 2 ft. near Acklam, expanding again to 10 ft. at the Humber (9).

The Speeton Clay represents the beds which come between the Gault and Kimmeridge Clay in the south of England.

It is 300 ft. thick at Speeton, but thins rapidly inland and cannot be traced far (4).

Oolitic.

During the whole of the Jurassic period the controlling factor in the variations of the thicknesses of the beds was an axis of upheaval (or non-subsidence) which ran east and west through Market Weighton. Along this axis both the Oolites and the Lias are either thin or missing, and it is only on its northern side that the Estuarine Beds attain their great development.

Kimmeridge Clay.

Near Knapton there is 500 ft. of black shale (7), which, however, probably includes some Speeton Clay. The Kimmeridge Clay is cut out over the Market Weighton axis, but on the south side by the Humber there is 100 ft. of clays, the upper part of which is probably Kimmeridgian.

Corallian.

In the northern parts of their outcrop the Corallian Beds are divided as follows:—

	Feet.
Upper Calcareous Grit	40
Upper Limestone and Coral Rag	50
Middle Calcareous Grit	50
Lower Limestone	60
Greystone or Passage Beds	40
Lower Calcareous Grit	130

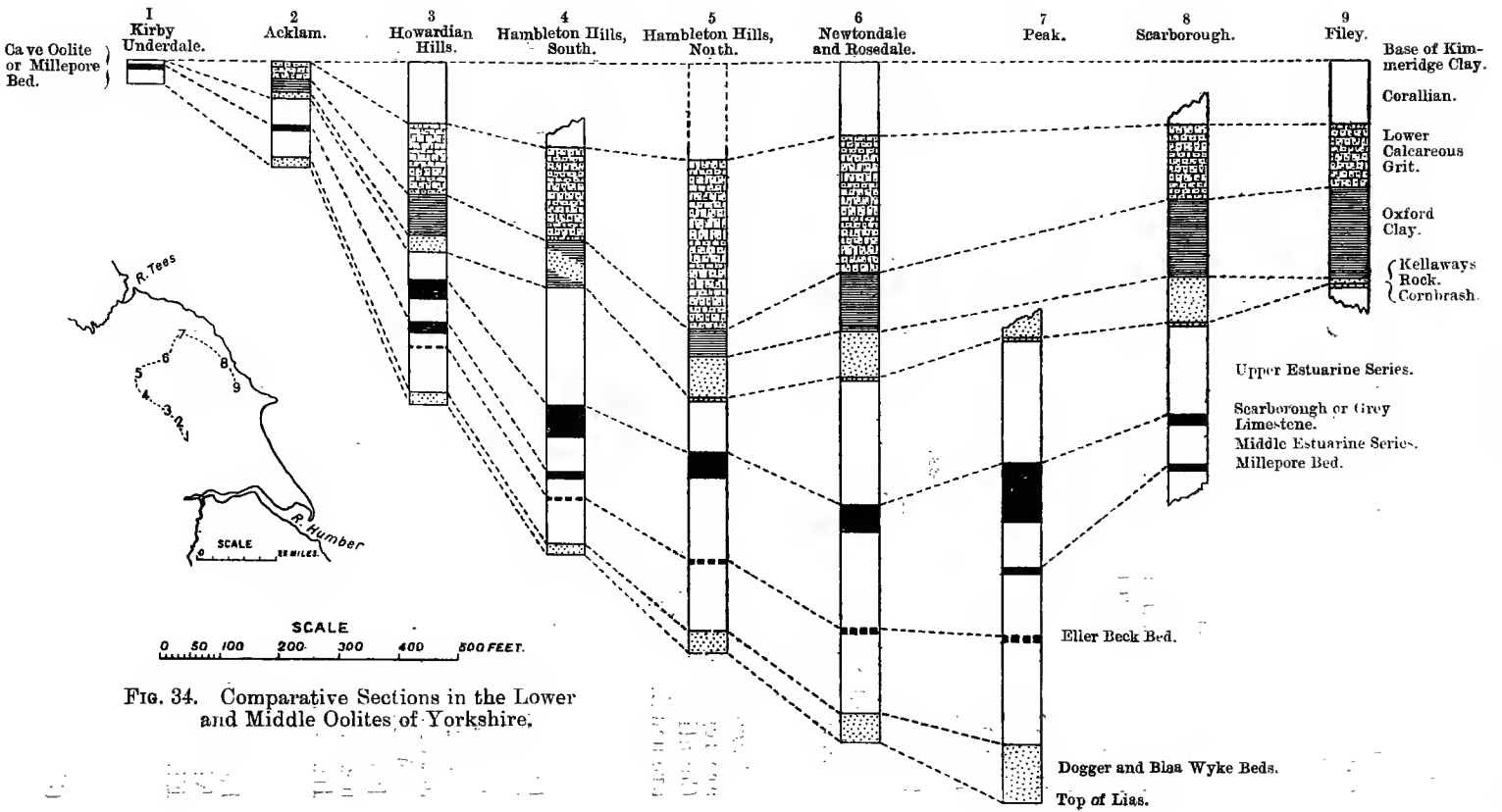


FIG. 34. Comparative Sections in the Lower and Middle Oolites of Yorkshire.

The thicknesses given relate to Kirkby Moorside, where they attain their maximum development (5).

The total thickness is greatly reduced on the south of the Vale of Pickering, being 160 ft. at Malton, 125 ft. at Grimston, and only 30 ft. at Acklam (5).

The Corallian group is absent over the Market Weighton axis, and to the south of it, when recognisable, is represented by clays.

Oxford Clay with Kellaways Rock.

The greatest thickness of the Oxford Clay is found north of Filey, where it amounts to 150 ft. (5). At Scarborough the formation reaches 120 ft., but over most of its northern and western outcrop it is from 50 to 70 ft. thick (5). Like the other Jurassic beds it thins over the Market Weighton axis, being 20 ft. at Acklam (5); but to the south it is overlapped by the Chalk. Near the Humber the lower part of the 100 ft. of clays referred to under Kimmeridge Clay is probably Oxfordian.

South of the Cleveland Hills and in the northern part of Hambleton Hills the Kellaways Rock, consisting of thick-bedded sandstone and sandy shales, is 70 to 100 ft. thick. At Scarborough it is 75 ft., but thins southward to 10 ft. at Filey and Acklam (5). It is absent over the Market Weighton axis but is 35 to 40 ft. thick south of this line. It thins again to the Humber, and ceases to be recognisable as a distinct bed.

Cornbrash.

Some hard ferruginous limestone and calcareous shale, which are regarded as corresponding to the Cornbrash of the Southern Counties, are developed in the northern part of Yorkshire and are usually about 10 to 16 ft. thick (5).

Upper Estuarine Series.

The Upper Estuarine Series at Peak is 200 ft. thick (5). In the district around Scarborough it varies from 124 to 200 ft., and in the Hambleton Hills from 100 to 200 ft. Further south at Brandsby and Kirkham it is about 50 ft. thick (5).

South of Kirkham the Upper and Middle Estuarine Series are not separable in the absence of the Scarborough Limestone.

At Acklam the beds between the Cave Oolite and the Kellaways Beds are 50 ft. thick. These thin southwards to less than 10 ft. near the Market Weighton axis, but thicken again to 20 ft. at the Humber.

Scarborough or Grey Limestone.

The Scarborough Limestone at Peak is 104 ft. thick; near Scarborough it varies from 7 to 20 ft., while from Cleveland to Kirkham it is generally between 30 and 50 ft. thick. South of Kirkham it thins away in clays and cannot be traced (5).

Middle and Lower Estuarine Series.

In the north-east of Yorkshire, at Peak, these beds attain a thickness of 390 ft.; at Hawsker they are about 285 ft. thick, at

Ruswarp 270 ft., in the Hambleton Hills 200 ft., and at Kirkham 150 ft. (5). At Kirby Underdale the Cave Oolite and Lower Estuarine Beds are 30 ft. thick, but in South Yorkshire have thickened to 80 ft. (5).

Cave Oolite or Millepore Bed.

The Cave Oolite is developed in the south of the Hambleton Hills and extends to the Humber. It forms the dividing line between the Upper and Lower Estuarine Series in this area and has a thickness varying from 10 to 30 ft. (5). In the north, on the coast, it is known as the Millepore Bed and has a maximum thickness of 20 ft. (5).

Dogger and Blea Wyke Beds.

The Dogger and Blea Wyke Beds are variable, sandy, ferruginous deposits having a thickness of 100 ft. at Blea Wyke Point, near Peak, and 70 ft. in Rosedale. In the Cleveland area they vary from 0 to 15 ft., but are always thin in the south (5).

Liassic.

The Upper Lias near Whitby is generally about 210 ft. thick, although at times it probably reaches 250 ft. (5). It thins southwards to 80 or 90 ft. in the district near Malton and over the Market Weighton axis is overlapped by the Chalk. Near the Humber it is about 40 ft. thick (5).

The Middle Lias is about 120 or 140 ft. thick in the north, but also thins southward, being 30 ft. near Malton and from 3 to 9 ft. in the Market Weighton area. In the Cleveland area the upper part contains valuable ironstone-bands. This Ironstone Series is 120 ft. thick at Robin Hood's Bay but thins to the northwest and west, being 93 ft. thick in Eskdale, from 60 to 80 ft. at Grosmont, and 60 ft. on the escarpment above Northallerton. ('Geology of Eskdale, etc.,' 1885, and 'Geology of North Cleveland,' 1888, *Mems. Geol. Surv.*)

The Lower Lias is estimated as having a total thickness of 800 ft., near Whitby (10). This becomes reduced southwards to 100–150 ft. between Malton and the Humber (1, 5, 8).

Triassic.

Rhaetic.

Around Northallerton there seems to be about 40 ft. of Rhaetic (10), consisting of black shales and limestones, while in Cleveland there are 20 ft. of these beds. In the south and in the Vale of York they are about 30 ft. thick (3). Tate and Blake give the black shales of the Rhaetic as being 14 ft. thick (1).

Keuper and Bunter.

The Keuper occupies the low ground of the valleys of the Ouse and the lower parts of the Swale and Tees. The Keuper Marl has been proved to be 700 ft. thick north-east of Selby, while in the Middlesbrough area it is probably between 500 and 600 ft.

In the northern part of the county the Keuper and Bunter cease to be distinguishable, and around Middlesbrough the sandstones are in the aggregate between 850 to 1,100 ft. thick; while the maximum thickness of 1,400 ft. has been proved north-east of Selby. A boring at Thorne showed that the full thickness of the Triassic sandstones there exceeds 856 ft. (3, 12).

Below the sandstones in the north of the county is a series of marls and saliferous beds of about 350 ft. in thickness.

Permian.

The Permian group thickens from 430 ft. in the extreme south of the county to 624 ft. at Selby (12) and to over 1,000 ft. north-east of that town. It is probably thinner in the districts between Knaresborough and Leeming Lane but thickens again to as much as 1,000 ft. in places near Middlesbrough (3, 11).

In the south of the county the beds are divided as follows (12):—

	Feet.
Upper Permian Marl	56–131
Upper Permian Limestone	42–109
Middle Permian Marl	34–125
Lower Permian Limestone	110–312
Marl Slate and Breccias	up to 24

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SOME BORINGS IN YORKSHIRE.

(Thicknesses in feet.)

	Armthorpe.	Thorne.	Snaith.	Carlton.	Reedness.	Marfleet.	Barlow.	Selby.	Hornsea.	Strensall.	Killington.	Filey.	Irton.	Leeming Lane.	Middlesbrough.
Alluvium	} 20	} 60	} 60	45	} 70	} 118	} 94	} 70	—	} 54	150	—	} 52	—	} 66
Glacial	}	}	}	—	}	}	}	}	120	}	—	189	}	34	}
Chalk	—	—	—	—	—	to 43	—	—	to 858	—	—	—	—	—	—
Red Chalk	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Speeton Clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kimmeridge Clay	—	—	—	—	—	—	—	—	—	—	to 244	75	47	—	—
Corallian	—	—	—	—	—	—	—	—	—	—	—	to 110	300	—	—
Oxford Clay	—	—	—	—	—	—	—	—	—	—	—	—	to 28	—	—
Kellaways Rock	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornbrash	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upper Estuarine Series	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scarborough Limestone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Middle and Lower Estuarine Series	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dogger and Blea Wyke Beds ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lias	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhaetic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trias	518	856	466	539	to 959	—	601	590	—	to 1107	—	—	—	161	to 1625
Permian	433	621	564	481	—	—	610	624	—	—	—	—	—	to 132	—

SOME ESTIMATES IN YORKSHIRE AREAS. (One-inch maps.)

(Thicknesses in feet.)

	York and Hull. Old Ser. 93 S.E., 94 S.W. New Ser. 71.	York & Malton. Old Ser. 93 N.E. New Ser. 63.	Scarborough. Old Ser. 95 S.W. and S.E. New Ser. 54, 55.	Malton. Old Ser. 96 S.E. New Ser. 53.	Whitby. Old Ser. 95 N.W. New Ser. 44.	Northallerton. Old Ser. 96 N.W. and S.W. New Ser. 42, 52.	North Cleveland Old Ser. 104 S.W. and S.E. New Ser. 34, 35.
Alluvium	90	30	—	—	—	50	—
Glacial	—	70	150	—	—	130	—
Chalk	1000	—	1100	—	—	—	—
Red Chalk	6	2 to 30	25	10	—	—	—
Speeton Clay	—	15 to 20	} 500	—	—	} 400	—
Kimmeridge Clay	—	200	}	—	—	}	—
Corallian	—	200	—	240	280	200 +	—
Oxford Clay	100 ?	20 to 70	150	80	—	50 +	—
Kellaways Rock	35	30	80	80	—	60	—
Cornbrash				2	10	—	14
Upper Estuarine Series			200		200	100 to 200	200
Scarborough Limestone	20 to 30	270	3 to 90		100	70	—
Middle and Lower Estuarine Series				450	280 to 400	250	270
Dogger and Blea Wyke Beds ...	10				to 95	6 to 50	—
Lias	to 200	250 +	—	160 +	860 +	—	—
Rhaetic	—	—	—	—	—	40	20
Trias	1200	1270	—	—	—	400 +	400 +
Permian	—	—	—	—	—	290 +	—

NORTH WALES.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium	to 75
	Glacial	to 284
Triassic ...	Lower Mottled Sandstone	859½
Palæozoic Rocks	... ...	—

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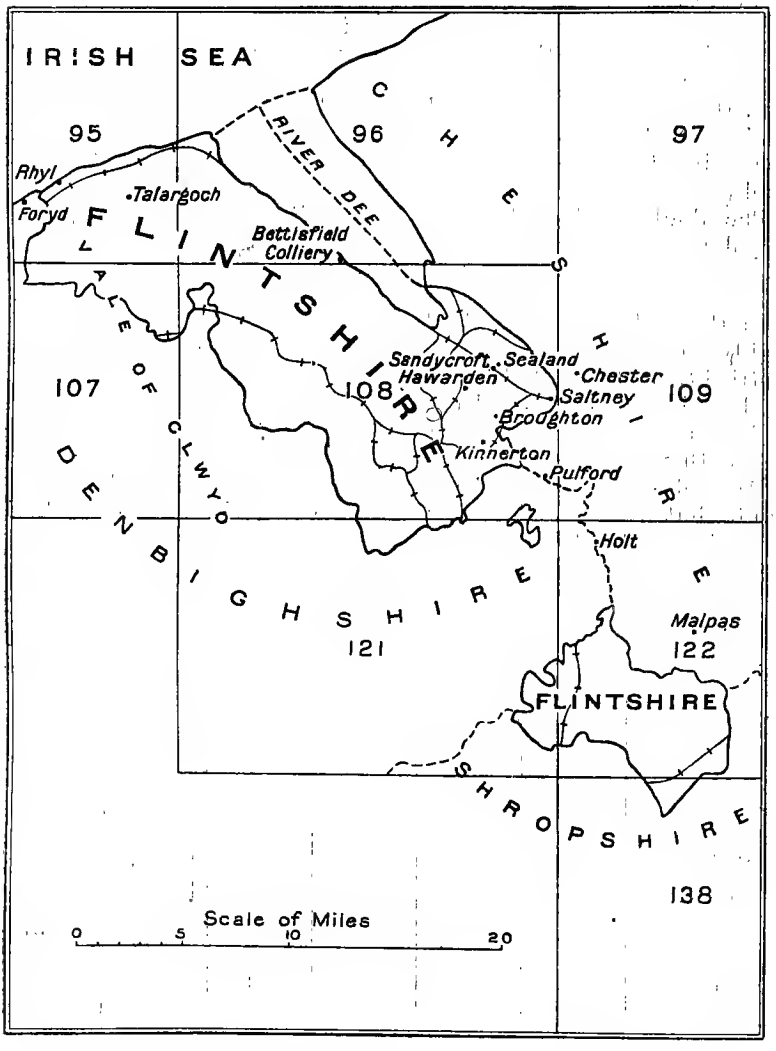
FIG. 35. NORTH WALES.



Superficial.

Alluvium.

The estuary of the Dee lies for the most part in Flintshire. As far up as Chester it is filled with alluvium resting generally on Boulder Clay. The alluvium consists of marine sand, which at Gorst's Farm, Sealand, was proved to be 75 ft. thick; at Bettisfield Colliery, 50 or 60 ft., and at Foryd, near Rhyl, 58⅓ ft. (3 and 2).

Glacial.

Glacial deposits cover most of the low-lying Triassic ground both in the Vale of Clwyd and in the Dee Valley.

The greatest thicknesses are attained along a preglacial valley of the Dee, which runs through Broughton, Lower Kinnerton, Pulford, to the west of Holt. The following thicknesses have been met with (3, 4):—72 ft. at Gorst's Farm, Sealand; 153 ft., No. 2 Sandycroft boring, Sealand; 228 ft. (not bottomed), No. 6 Hawarden Castle Colliery boring, Manor Hall Farm; 272 ft. (not bottomed), Lower Kinnerton.

In the Vale of Clwyd the glacial beds were upwards of 284 ft. thick at the Talargoch Mine. In both the Vale of Clwyd and the Dee Valley there are large areas where the solid rock is below sea-level (2, 3).

The Boulder Clay along the Welsh Border is generally stiff chocolate-coloured calcareous clay with few boulders.

Triassic.

In the Vale of Clwyd the Trias is represented by a soft red highly current-bedded sandstone which is assigned to the Lower Mottled Sandstone. It has been proved to be not less than 500 ft. thick at Foryd, near Rhyl (2).

Triassic rocks occur also on the Welsh Border. The greatest proved thickness is 859½ ft., in Sealand (3).

Most of the Trias of the Welsh Border is assignable to the Bunter but Keuper Beds come within a detached part of Flintshire which lies south of Malpas in Cheshire:—

Some borings in North Wales.

Thicknesses in feet.

	Foryd.	Talargoch.	Gorst's Farm, Sealand.	No. 2 Sandy-croft.	No. 3 730 yds. S.S.W. St. Bartholomew Church.	Saltney.
Alluvium ...	58	—	75	42½	43	27
Glacial... ...	40	to 284	72	153	30½ to 6	151½
Trias	499	—	—	—	859½	to 197½
	to		to	to	to	
Carboniferous...	149½	—	225	491	698	—

SOUTH WALES.

Table of Strata.

		Thickness in feet.
Superficial	Alluvium, &c.	to 64
	Glacial	to 300
Liassic ...	Lower Lias	to 277
Triassic ...	Rhaetic	18–33
	Keuper	to 400
Palæozoic Rocks	... ...	—

Authorities.

1. Jurassic Rocks of Britain, *Mem. Geol. Surv.*, vol. iii, 1893.
2. Geology of the Country around Bridgend, *ib.*, 1904.
3. Geology of West Gower and the Country around Pembrey, *ib.*, 1907.
4. A. Strahan. Geology in the Field, *Geol. Assoc.*, 1910, p. 826.
5. Geology of the Country around Cardiff, *Mem. Geol. Surv.*, 2nd Ed., 1912.
6. Geology of the Country around Swansea, *ib.*, 1907.

Superficial.

Alluvium and Gravel.

The alluvial deposits which border the estuary of the Severn range from 30 to 50 ft. in thickness near Newport and Cardiff. They include silts, layers of peaty matter, and occasionally old land-surfaces with tree-stools in position of growth. The lowest land-surface observed, in the Barry Docks, lay at 35 ft. below Ordnance Datum (5).

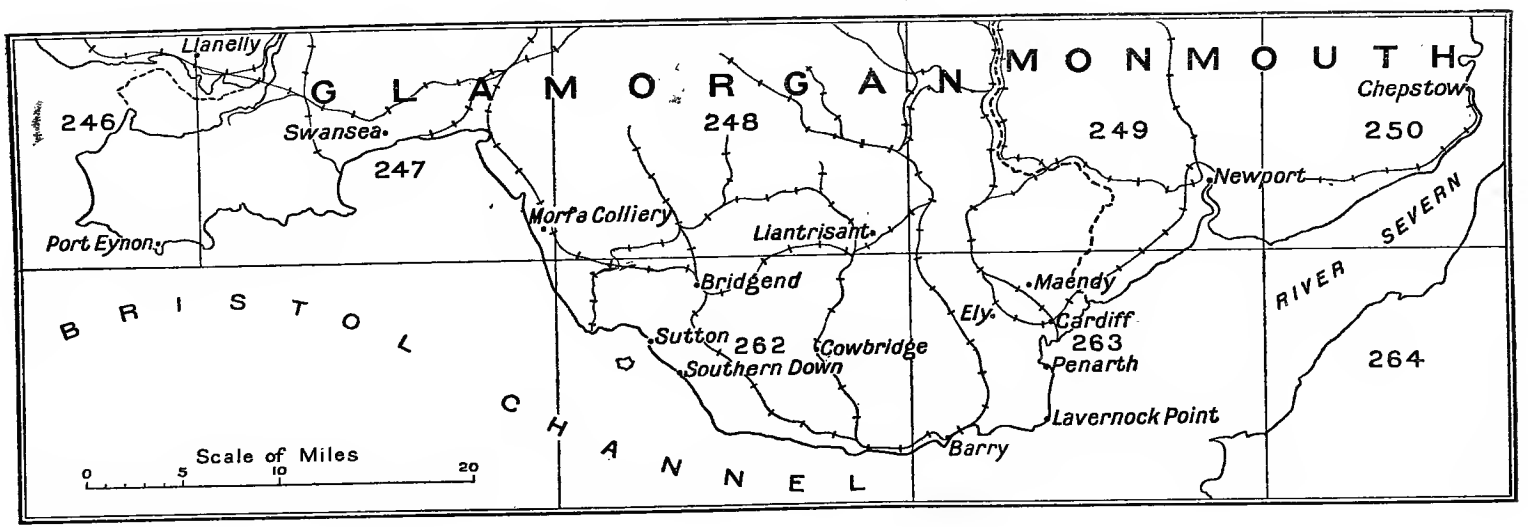
The gravel-terrace on which much of Cardiff is built varies from 8 to 20 ft. in thickness.

Farther west, at the Morfa Colliery, the depth from the level of the Margam Marsh to the surface of the rock was 71 ft. 10 ins., but in this was included 29 ft. 4 ins. of clay and gravel which may be of Glacial age. In the alluvial flats near Briton Ferry the depth to the rock varies 50 to 100 ft., and in the Tawe Valley, three miles above Swansea, about 60 ft. of clay and quicksand were encountered, with trees embedded at a depth of 20 ft. Near Llanelly alluvial deposits similar to those of the coast near Cardiff extend to a depth of more than 64 ft. (6).

Glacial.

The Glacial deposits attain great depths in the valleys, but for the most occupy narrow strips. In the Tawe Valley, at Swansea, glacial gravel extends to a depth of 300 ft., down to a level 150 ft. below Ordnance Datum (6). Many records of these extremely variable deposits will be found in the Memoirs on the South Wales Coal Field and in the Vertical Sections of the Geological Survey, Sheets 80, 81, 83-85, 87.

Fig. 36. South Wales.



Liassic.

The highest beds of the Lias left by denudation in Glamorganshire belong to the Semicostatus Zone of the Lower Lias, and the total thickness of the beds above the top of the Rhaetic is estimated at 277 ft. (2).

The Lower Lias, however, appears in South Wales under two aspects. In the one it keeps its normal character as a series of alternating clays and limestones, while in the other it consists of conglomerates and limestone-breccias, evidently littoral deposits accumulated in the immediate neighbourhood of Liassic coast-lines.

The lowest beds of the littoral type are known as the Sutton Series, and are from 25 to 40 ft. thick, but vary rapidly owing to the inequalities of the surface of Carboniferous Limestone on which they rest.

Above the Sutton Series is the Southerndown Series, which is about 50 ft. thick in places, and consists of hard massive bluish conglomeratic limestones and shales (2). These shore-deposits of a sinking area are each in turn overlapped by higher beds and are not always present.

Triassic.

Rhaetic.

Rhaetic Beds and Keuper Marl are well represented in South Wales, but Keuper and Bunter Sandstones are absent. The Rhaetic, like the Lias, appears under a normal and a littoral aspect. In the districts of Penarth and Chepstow it consists of white marls and black shales with thin limestones, all of normal type. At Lavernock Point the upper 11 ft. belong to the White Lias, below which comes about 22 ft. of black shales with the bone-bed near the base and a thin conglomerate resting in pockets in the tea-green marls. At Chepstow the Rhaetic is 18 ft. thick.

The littoral facies of the Rhaetic commences near Cowbridge and becomes increasingly abnormal westwards. The shales first pass into a massive oolite and farther on into a massive sandstone (2, 5).

Keuper Marl.

The distribution of the Keuper Marl is influenced by the Triassic topography. The Keuper main-land lay to the north of a curving line running more or less east and west and passing a little south of Llantrisant. Offshore there were several islands, the chief of which lay south of Bridgend and extended from the east of Cowbridge to the sea near Southerndown.[1] On the slopes of each of these land-areas lie breccias composed of their detritus, while farther away marls appear among the breccias and eventually wholly replace them. On these slopes too each member of the Trias in turn overlaps its predecessor and comes to rest on the palæozoic rocks.

[1] See map in 'The Geology of the Country around Bridgend,' *Mem. Geol. Surv.*, 1904, p. 24, and reproduced in 'The Geology in the Field,' *Geol. Assoc.*, 1910, p. 845.

The highest beds of the Keuper are the tea-green marls, which have an average thickness of from 20 to 45 ft. (5). These graduate downwards into red marls of the usual type except where they rest on the old land-surface, when they pass into breccia (2).

The greatest thickness of the Keuper seems to be about 400 ft. near Cardiff, but under the circumstances referred to above the depth of marl varies greatly.

A small outlier of conglomerate, which occurs at Port Eynon, forms the most westerly exposure of the Trias (3).

On the banks of the Severn the Keuper presents the normal type of tea-green marls above and red marls below.

SOME BORINGS AND ESTIMATES IN SOUTH WALES.

Thicknesses in feet.

	Chepstow.	Sections in railway cutting near Cowbridge.		Maendy.	Ely.	Cardiff.
Alluvium and Glacial	—	—	—	20	26	49
Lias	37	65	1	—	—	—
Rhaetic	18	13½	19⅔	—	—	—
	to	to				
Keuper	76	8	1	60	117	367
Carboniferous and older			to	to	to	to
rocks	—	—	—	40	257	649

A.

B.

* *Table following the page named.*

* *Table following the page named.*

C.

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D.

E.

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T.

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U.

V.

W.

* *Table following the page named.*

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